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HABITABILITY OF THE LOVE CANAL AREA

AN ANALYSIS OF THE TECHNICAL BASIS FOR THE DECISION ON THE HABITABILITY OF THE EMERGENCY DECLARATION AREA

A TECHNICAL MEMORANDUM

JUNE 1983

Technical Memoranda are issued by OTA on specific subjects analyzed in recent OTA reports or on projects presently in process at OTA. They are issued at the request of Members of Congress who are engaged in committee legislative actions which are expected to be resolved before OTA completes its assessment.

CONGRESS OF THE UNITED STATES
Office of Technology Assessment
Washington, D. C. 20510

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Foreword

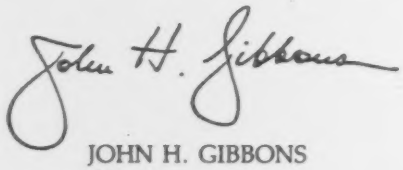
In December 1982, OTA was requested by Senators Daniel Patrick Moynihan and Alfonse D'Amato of New York to perform a case study of Love Canal. The request came at a time when OTA was completing its 3-year study of hazardous wastes. OTA's report *Technologies and Management Strategies for Hazardous Waste Control* was released in March 1983. OTA's larger study on hazardous wastes formed the basis for the case study on Love Canal.

The principal goal of the case study was to examine the technical basis for, and validity of, the habitability decision for the emergency declaration area near Love Canal. This decision was made by the Department of Health and Human Services, and was based principally on the results of a monitoring study conducted by the Environmental Protection Agency. OTA was also asked to examine the current monitoring and cleanup activities at Love Canal, and the plans for future remedial action.

This technical memorandum consists of three principal sections:

1. OTA's findings on the habitability decision, and the four arguments on which they are based.
2. An outline of the steps that could be taken to safely achieve incremental rehabitation of the emergency declaration area.
3. Implications of the results of this case study for the national Superfund program for uncontrolled hazardous waste sites, under which cleanup at Love Canal is proceeding.

The timely completion of this study was made possible by the extensive assistance provided by many people at several New York State agencies, the Environmental Protection Agency, the Department of Health and Human Services, and the National Bureau of Standards.



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Acronyms, Abbreviations, and Terms

Acronyms and Abbreviations

ACGIH — American Conference of Government Industrial Hygienists
ACS — American Chemical Society
C — control areas sampled by EPA monitoring study
CDC — Centers for Disease Control, Public Health Service, U.S. Department of Commerce
CERCLA — Comprehensive Environmental Response, Compensation, and Liability Act of 1980, 42 U.S.C. 9601 et seq., known colloquially as "Superfund"
DHHS — U.S. Department of Health and Human Services
EDA — emergency declaration area
EDF — Environmental Defense Fund
EPA — U.S. Environmental Protection Agency
FEMA — Federal Emergency Management Act of 1978, CFR Title 44, Part 2, and associated Agency
GAO — General Accounting Office, U.S. Congress
gpm — gallons per minute
IARC — International Agency for Research on Cancer, U.N. World Health Organization
LCARA — Love Canal Area Revitalization Agency
LOD — limit(s) of detection
LOQ — limit(s) of quantitation
MDL — method detection limit(s)
NAS — National Academy of Sciences
NBS — National Bureau of Standards, U.S. Department of Commerce
NCI — National Cancer Institute
NTP — National Toxicology Program
NYS/DEC — New York State Department of Environmental Conservation
NYS/DOH — New York State Department of Health
NYS/DOL — New York State Department of Law
OTA — Office of Technology Assessment, U.S. Congress
ppb — parts per billion, equal to micrograms per liter in water, micrograms per kilogram in solids or gases
ppm — parts per million
ppt — parts per trillion
RCRA — Resource Conservation and Recovery Act of 1976, 42 U.S.C. 6901 et seq.
TLV — threshold limit value
TSCA — Toxic Substances Control Act of 1976, 15 U.S.C. 2601 et seq.
μg/kg — micrograms per kilogram, equal to ppb in solids or gases
μg/l — micrograms per liter, equal to ppb in water

Terms

emergency declaration area (EDA): area sampled by EPA monitoring study, outside 49-acre area surrounding the canal landfill, divided by EPA into 10 subregions for sampling purposes.

environmental medium: one of five environmental components sampled by EPA, including water, soil, sediment, air, biota.

environmental submedium: 1 of 22 components of the five environmental media

indicator substances: substance which was known to have been disposed into canal landfill

Love Canal: 49-acre area including canal landfill sampled by EPA monitoring study

target substance: 1 of 50 substances monitored in EPA monitoring study

Chapter 1

Executive Summary

Chapter 1

Executive Summary

SUMMARY

In 1980, the Federal Government decided that a potential health threat existed in an area near Love Canal, beyond the canal itself and two inner rings. This outer area was termed the emergency declaration area (EDA). In cooperation with New York State, the Federal Government provided assistance for residents who wished to move out of the area. There was no clear evidence at the time of substantial and widespread contamination of the EDA by toxic chemicals from Love Canal.

From August to October 1980, the Environmental Protection Agency (EPA) conducted a monitoring study to provide evidence for determining whether the EDA was contaminated or could become so. Later, the Department of Health and Human Services (DHHS) became responsible for deciding, on the basis of the EPA study and other data, whether the EDA was habitable. In July 1982, after considering comments by the National Bureau of Standards (NBS) on the procedures EPA had used, and after further consultation with EPA, DHHS affirmed its earlier provisional decision that the EDA was habitable. The decision was contingent on effective safeguards against leakage from the canal, and cleaning up contamination in the EDA.

OTA has reviewed and analyzed the EPA monitoring study, documents prepared by other Federal agencies, plans for remedial action developed by EPA and New York State, and various independent critiques. OTA's primary goal was to examine the technical basis for the decision reached by DHHS, in conjunction with EPA, that the EDA is habitable.

OTA's principal finding is that: **With available information it is not possible to conclude either that unsafe levels of toxic contamination exist or that they do not exist in the EDA. The OTA analysis does not support an interpretation of the DHHS decision that would lead to the immediate and complete rehabitation of the EDA. There remains a need to demonstrate more unequivocally that the EDA is safe immediately and over the long term for human habitation. If that cannot be done, it may be necessary to accept the original presumption that the area is not habitable.**

Four arguments that support the principal finding are:

1. The current activities and long-term plans for EDA cleanup and operation and maintenance of the Love Canal remedial action program pose difficulties and uncertainties.
2. The design of the EPA monitoring study, particularly its sampling strategy, was inadequate to detect the true level and pattern of toxic chemical contamination that might exist in the EDA.
3. The EPA monitoring study contains important uncertainties over the levels of the toxic chemicals detected, and the possible levels of those not detected. There are also uncertainties over possible synergistic human health effects of multiple toxic chemicals present at low concentrations. These two areas of uncertainty, as well as the lack of detailed documentation by DHHS of its analyses, place the decision on habitability by DHHS in doubt.
4. OTA's analysis of some data obtained in the EPA monitoring study provides limited, but not conclusive, indication that there may be contamination in the EDA by toxic chemicals from Love Canal. OTA examined those data for chemicals known to have been disposed in Love Canal, as compared to the much larger universe of data analyzed by EPA.

Incremental rehabitation of the EDA is a possible alternative to complete rehabitation, or to a presumption that the area is not habitable. OTA has outlined several steps that could be taken to move in this direction. By incremental rehabitation we mean a paced, cautious approach. Improvements in scientific certainty to assure safe-

ty of the EDA are necessary for the success of this approach. Another benefit of improved certainty is to increase public confidence in policy decisions that are based on technically complex data and analyses. Four key steps for moving toward incremental rehabitation are:

1. To address the technical problems and uncertainties in the current cleanup activities in the EDA and in the long-term plans for operation and maintenance of the waste containment system at Love Canal.
2. To address the uncertainties related to institutional stability and effectiveness over the very long terms (i.e., hundreds of years) that reflect the long lifetimes of the chemicals in Love Canal.
3. To consider performing additional monitoring for carefully defined areas of the EDA, perhaps for individual homesites. This would make use of what has been learned from the EPA monitoring study.
4. To develop a program for finding a permanent solution to deal with the large amounts of toxic wastes still in Love Canal (i.e., waste destruction or detoxification instead of the waste isolation approach now in effect).

OTA's case study of the Love Canal EDA touches on a number of issues of general importance to the Federal Superfund program for cleanup of uncontrolled hazardous waste sites. EPA is now aware of about 16,000 uncontrolled hazardous waste sites nationwide. The use of monitoring studies to answer questions on relocation and habitability will likely continue to be necessary. Therefore, it is important to learn as much as possible from the Love Canal experience to make future efforts more effective and efficient. There are needs to:

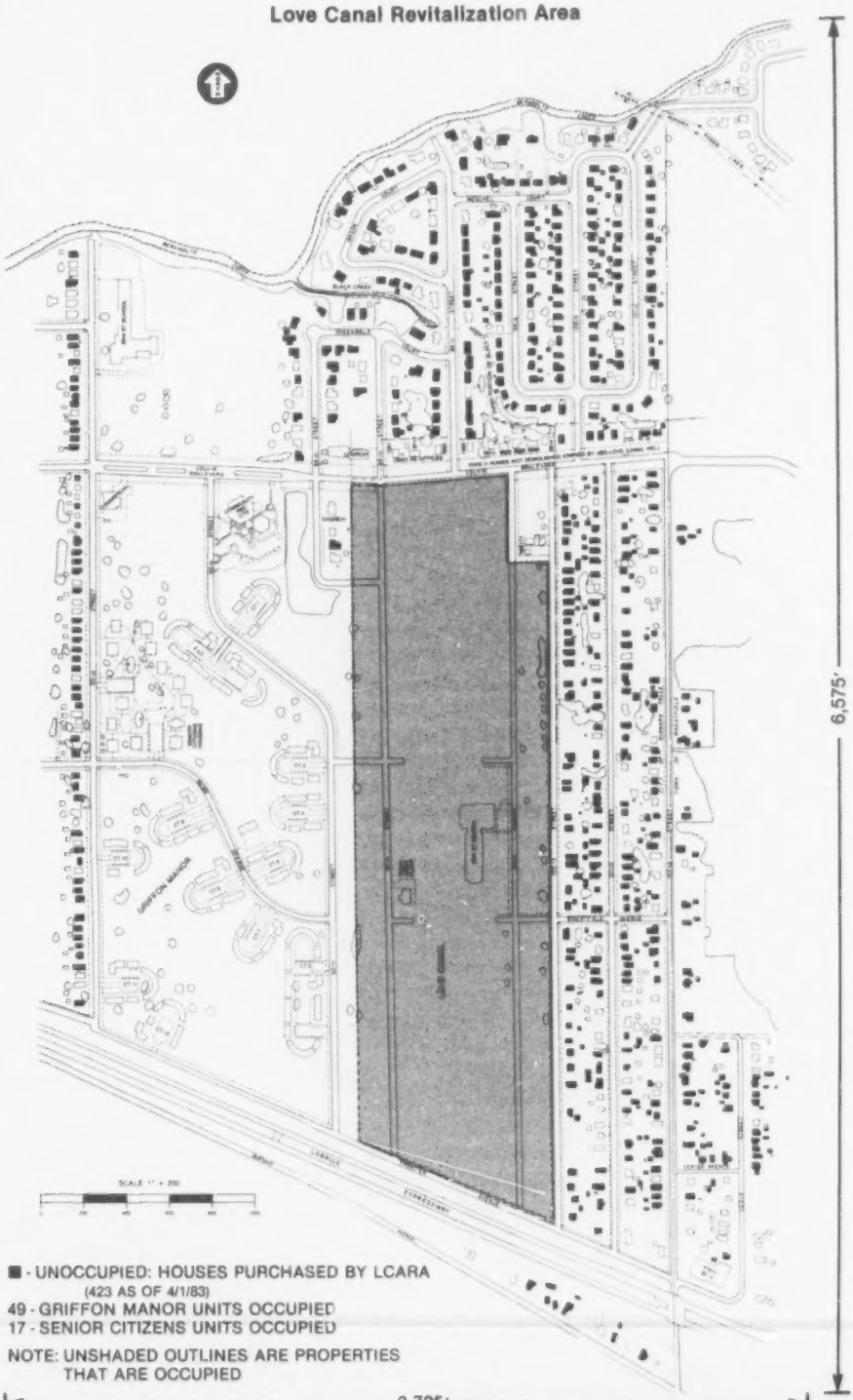
- Examine the "How clean is clean?" question, and to develop standards for unacceptable levels of contamination by toxic chemicals.
- Obtain much more information on the health effects of toxic chemicals, and better define the Federal decisionmaking process concerning habitability of, and relocation of residents from, uncontrolled hazardous waste sites.
- Develop technical guidelines for monitoring studies, particularly for sampling and analytical protocols, and for the way results are presented and documented.
- Compel consideration of more permanent solutions for cleaning up uncontrolled waste sites, and to develop ongoing programs to evaluate technological opportunities for eventual permanent solutions to replace waste containment "interim solutions." It is also necessary to improve oversight by EPA of State implementation of chosen remedial action programs.
- Explore answers to problems of long-term institutional effectiveness, such as mechanisms to assure indefinite funding for operating and maintaining waste containment systems.

BACKGROUND

In 1980, the Federal Government decided that a potential health threat existed beyond the canal (shaded area on figure) itself. The outer area was termed the emergency declaration area (EDA). See the accompanying figure for a description of the EDA and Love Canal areas. In cooperation with New York State, the Federal Government provided assistance for residents who wished to move out of the area. Not all residents in the EDA decided to relocate. The canal itself and Rings 1 and 2 had been the subject of an earlier Federal state of emergency which included total evacuation and intensive cleanup efforts. As for the EDA, there was no clear evidence at the time of the emergency declaration that substantial and widespread contamination by toxic chemicals existed in the area. The voluntary evacuation was considered a precautionary measure.

Nevertheless, Government actions have raised the issue of habitability of the EDA. These actions included: providing assistance for relocation, implementing monitoring studies to determine if contamination was present (and at what levels and patterns), carrying out studies on possible health effects among residents of the EDA, and implementing the cleanup program to correct the known problems in the canal itself and the adjacent rings. In light of these activities, the hab-

Love Canal Revitalization Area


6,575'
3,725'
■ - UNOCCUPIED: HOUSES PURCHASED BY LCARA
(423 AS OF 4/1/83)
49 - GRIFFON MANOR UNITS OCCUPIED
17 - SENIOR CITIZENS UNITS OCCUPIED
NOTE: UNSHADED OUTLINES ARE PROPERTIES
THAT ARE OCCUPIED

BEST AVAILABLE COPY

itability of the EDA became, and still remains, an important issue.

Government agencies anticipated that scientific evidence of no contamination, or of acceptably low levels of contamination, would be necessary before people could be allowed to move back into the evacuated portions of the EDA. From August to October 1980, EPA conducted a monitoring study to provide evidence for determining whether the EDA was contaminated by toxic chemicals from Love Canal, or could become so. The related, difficult task of deciding whether or not the EDA was habitable was undertaken by DHHS. DHHS was to make its decision primarily on the basis of the EPA monitoring study, but was also to consider other data on contamination levels and on health-related problems observed in residents, as well as professional judgments about possible health effects that could result from exposure to chemicals present in the EDA.

EPA asked NBS to examine the analytical chemistry procedures EPA used in its monitoring study. After completion of the initial NBS report in May 1982, DHHS requested NBS to explain the significance of the negative data in the EPA study. Ninety percent of the samples taken by EPA had revealed either no detectable levels or trace amounts of contamination. DHHS wanted to be satisfied that the data were reliable enough to allow the conclusion that, in fact, only very low levels of chemicals were detected. The possibility that EPA's analytic techniques may have missed contamination in the low parts-per-billion range had to be considered. DHHS was satisfied with EPA's responses to the NBS comments on this matter. In July 1982, DHHS affirmed its earlier provisional decision that the EDA "is as habitable as the control areas with which it was compared." However, DHHS made its decision on habitability contingent on the understanding that the canal site itself and Rings 1 and 2 would be "constantly safeguarded against future leakage from the canal and that cleanup is required for existing contamination of local storm sewers and their drainage tracts [in the EDA]."[1]

[1] "DHHS Evaluation of Results of Environmental Chemical Testing By EPA in the Vicinity of Love Canal—Implications for Human Health—Further Considerations Concerning Habitability" (Washington, D.C.: Department of Health and Human Services, July 13, 1982).

It must be stressed that EPA's monitoring task for a large area possibly contaminated by hundreds of different chemicals was historically unique, technically complex, and very large in scope. EPA had no precedent for a similarly broad and complex monitoring study, targeted toward a decision on whether a site possibly contaminated by toxic wastes was habitable or rehabitable. Time for the study was severely constrained because of the Government's strong desire to make a policy decision on habitability. The effort was further complicated by other factors:

1. Information on the existing or potential migration of chemicals from the canal was lacking.
2. Boundaries for the EDA were arbitrary, unrelated to technical considerations of possible routes of transport of chemicals from the canal.
3. The time constraints ruled out a pilot study to define the requirements for the larger monitoring program (e.g., to identify qualitatively the levels of contamination to be expected, thus influencing sampling design and the choice of analytical procedures).

The findings of the study, moreover, made a habitability decision difficult. The discovery of high levels of contamination of even a few chemicals can provide a reasonably certain basis for a decision of "nonhabitability," but it is far more difficult to contend with a situation involving low levels of contamination. The latter was the unexpected result of the EPA monitoring study. Did the low levels of contamination in the EDA found by EPA accurately reflect reality? For the general public as well as technical experts, there were concerns about the sampling, analysis, and interpretation of EPA's data. Thus, the goal of reaching a policy decision on habitability quickly was not met. Interpretation of the data collected by EPA was difficult in itself. In addition, a number of parties raised questions about the study which required further analysis.

The problems confronting New York State in the Love Canal cleanup were also unique, difficult, and complex. Love Canal was one of the first

major uncontrolled hazardous waste sites in the Nation where remediation was attempted. There was a paucity of previous experience to offer guidance on the technological problems of short-term cleanup and long-term maintenance. These problems must be solved. Moreover, EPA's Superfund program has not yet reached the stage of providing complete, effective technical and policy guidance on remediation.

THE OTA ANALYSIS

Scope of the OTA Analysis

At the request of the two U.S. Senators from New York, and based on OTA's previous work on hazardous waste,[2] OTA reviewed and analyzed the EPA monitoring study, documents prepared by DHHS and NBS, the plans for remedial action developed by EPA and New York State, and various independent critiques. OTA focused on the technical aspects of sampling design and analytical procedures used to obtain monitoring data, on the statistical methods used to evaluate the data, and on the immediate and long-term remediation plans for the entire Love Canal area. It was not OTA's task to reach a finding concerning habitability of the EDA or to obtain new monitoring data. OTA's primary goal was to examine the technical basis for the decision already reached by DHHS in conjunction with EPA. OTA was also asked to consider possible implications of this case study for the national Superfund program for cleaning up uncontrolled hazardous waste sites.

[2] *Technologies and Management Strategies for Hazardous Waste Control* (Washington, D.C.: U.S. Congress, Office of Technology Assessment, OTA-M-196, March, 1983).

The principal findings:

1. **With available information it is not possible to conclude either that unsafe levels of toxic contamination exist or that they do not exist in the EDA.**
2. **There are also serious concerns and uncertainties about progress in the remedial program to date and plans for the future.**

The OTA analysis does not support an interpretation of the DHHS decision that would lead to the immediate and complete rehabitation of the EDA. **There remains a need to demonstrate more unequivocally that the EDA is safe for human habitation immediately and over the long term. If that cannot be done, it may be necessary to accept the original presumption that the area is not habitable.**

The three following sections discuss:

1. Four arguments that support the above findings, with the more detailed supporting analyses provided in an appendix to this report.
2. A number of Federal and State actions that might be undertaken for incremental rehabitation of the EDA over time.
3. Implications and issues for the national Superfund program of the Love Canal case.

THE FOUR ARGUMENTS FOR OTA'S PRINCIPAL FINDINGS

1. **The current activities and long-term plans for EDA cleanup and operation and maintenance of the Love Canal remedial action program pose difficulties and uncertainties.**

Regardless of whether contamination of the EDA by toxic chemicals exists now, rehabitation of the EDA requires assurance about the future. The current activities and long-term plans for cleanup of the entire canal area and for isolation of the wastes remaining in the canal must be effective (see the appendix for a description of these activities and plans). Effective cleanup was a critical contingency in the DHHS decision on habitability, for two main reasons:

1. in several areas of the EDA there are confirmed high concentrations of dioxin which

pose a threat either if the dioxin stays where it was found originally or if it migrates elsewhere; and

2. there remain in the canal itself very large amounts of toxic wastes and contaminated soil, both of which pose threats unless they are safely isolated from the environment, totally removed, or permanently destroyed or detoxified onsite.

The remediation approach at Love Canal is containment of the toxic wastes so that there is no migration of toxic chemicals into the surrounding environment. This approach raises the question of what is meant by "long-term" in containing these wastes. *Both technically and institutionally, "long-term" for toxic wastes must be interpreted to mean hundreds or thousands of years.* Why is it necessary to go beyond several decades in assuring the effectiveness of the containment system? Because many of the toxic chemicals present in the canal area are expected to remain stable and hazardous indefinitely. It is difficult to conceive of sanctioning rehabitation in the areas most exposed to leakage of toxic chemicals from the canal area without a high level of confidence that the remediation plan will remain effective beyond the next few decades.

OTA sees three major reasons for concluding, at present, that further attention must be given to site cleanup and remediation before rehabitation of the EDA can proceed.

First, *the areas in the EDA contaminated with high levels of dioxin have not yet been cleaned up.* Moreover, until just a few months ago storm sewers leading from the canal area to the EDA and known to contain dioxin remained open. It is possible that during the past few years—after completion of the EPA monitoring study—dioxin may have been transported within or beyond the EDA. A study to determine the full extent of contamination in and near the sewers is not yet completed. When it is completed, it will greatly assist the cleanup effort.

Second, *there are technical problems with the current activities and plans for the canal itself and the immediate rings.* These include:

- *Leak Detection Systems.*—The long-term integrity of the remedial technology is not certain. Reliable methods are needed to allow early detection of damage (leading to permeability) to the two basic elements of the containment system. These elements, intended to minimize water entering the canal, are the cap over the canal area and the concrete barrier wall to be built around it. There is no dispute about the need for repair and replacement of the cap and leachate collection system over time, Yet, how it will be done is not clear. How structural damage or clogging of the drain system will be detected, and how repair and replacement can be carried out safely remain unanswered.
- *Monitoring Programs.*—Assurance of sufficient warning about any potential migration and accumulation of chemicals from the canal is essential. Plans are underway for developing a long-term monitoring plan for ground water in the area immediately adjacent to Love Canal, but not in the EDA. In this same area (adjacent to Love Canal) it is also necessary to design more extensive ambient monitoring of environmental media other than ground water (e.g., air, soil, and biota). Media other than ground water are possible routes of exposure to toxic chemicals. For example, depending on the properties of chemicals disposed in the canal and the soil through which the ground water moves, some chemicals could be filtered out and could accumulate in soil or possibly in biota. Humans might become exposed to either. In addition, damage to the cap could allow release of volatile compounds into the air.

A third major area of uncertainty concerns the long-term ability of government institutions to remember, fund, and carry out commitments for long-term continued monitoring and maintenance of the site. The full range of institutional issues surrounding very long-term commitments for managing uncontrolled hazardous waste sites under the Superfund program have nowhere yet been fully addressed. New York State is not alone in facing these questions. But Love Canal is something of a historical first, and may be viewed as a model. Annual cost estimates for routine operation and maintainance, as well as for replacement, of the leachate collection system at Love Canal

are about $0.4 million now, $4.2 million in the year 2005, and $8.5 million in 2030. These costs could rise if the other leak detection and monitoring needs noted above are found to require attention. Even though the present State administration is committed to providing these funds, there is no guarantee that State officials 20 or 100 years from now will either remember or honor this commitment.

It is reasonable to raise the prospect that even larger funds might be needed at some time to take further corrective action at the Love Canal site if the original containment system were to fail. Furthermore, there are few institutional mechanisms in place to assure continuity in transferring vital information on Love Canal from one generation to the next. Nor does it appear that New York State has taken binding and permanent title to the canal area in a manner that unequivocally rules out future use of the site.* Finally, the idea that the present containment system is no more than an acceptable "interim solution" requires more attention. No specific program has been undertaken to find a more permanent remedy for removing, destroying, or detoxifying the wastes in the canal.

2. The design of the EPA monitoring study, particularly its sampling strategy, was inadequate to detect the true level and pattern of toxic chemical contamination that might exist in the EDA.

The principal finding of the EPA monitoring study was that, except for a few locations with high levels of dioxin and some other chemicals, there were insignificant levels and patterns of contamination in the EDA attributable to wastes in Love Canal. The finding was based on analysis of the samples taken in the EDA. Our concern is that the design of the monitoring study was not adequate to detect all significant contamination that might be present.

The uncertainties which OTA sees as critical involve such aspects of design as how many samples were taken for specific chemicals, in how many locations within the EDA, and in what environmental media. Whether a monitoring study detects contamination depends on how the search is conducted. If the design of a monitoring study is inadequate, then an erroneous false-negative interpretation may result.

The absence of a strong positive finding of contamination does not at all imply that a negative finding (absence of contamination or absence of health effects) follows logically or persuasively. In the case of a monitoring study, particularly one carried out under serious time constraints and without the benefit of a pilot study, sampling inadequacies can lead to a low level of confidence in the results. While there may never be absolute confidence that a study can find what it is looking for, the issue in the case of the EPA monitoring study is that the confidence level is low.

This lack of confidence in negative results (the finding of an absence) presents substantial problems to policymakers who desire a firm, scientific basis for decisionmaking, but it is sometimes an inevitable outcome of scientific studies. Scientists themselves often find it difficult to give an answer of "I can't determine, or I'm not sure" rather than a "yes or no" answer. Low confidence in the design of a study to produce the desired information, it should be noted, is not the same as scientific uncertainty over the results of a study; uncertainty is discussed in a later section.

The following specific problems with the sampling procedures used by EPA led OTA to judge the outcome of the study indeterminate with regard to the extent (or distribution) and level of chemical contamination, and its site and regional variability:

- The monitoring study sampled unevenly across environmental media and the 12 regions (10 in the EDA, the canal, and the control). The numbers of sampling sites were not in proportion to sizes of the regions, which vary by a factor of 10. One reason for this situation was that EPA assumed that higher levels of contamination existed closer to the canal. Consequently, some regions farther away from the canal had very little sampling;

*This is not to imply that there is any serious consideration being given to reuse of the canal. But some people may raise this prospect for the future. Reuse already took place once, when governmental bodies deemed the canal area safe for community development after it was no longer used for waste disposal.

the distribution of sampling among regions in the EDA was particularly inadequate. Initial beliefs about possible routes of transport of toxic chemicals from the canal to and through the EDA may also have influenced numbers of sampling sites in environmental media. To the extent that these assumptions about patterns remain unproven or unsupported by the results of the study, it can be concluded that the sampling may not have detected contamination present in the EDA which does not correspond to the patterns assumed initially by EPA.

- The numbers of sampling sites used were insufficient to determine accurately the level of contamination within some regions.
- As for environmental media, the extent of sampling was very broad and included air, surface and ground water, soil, sediment, and biota. However, the effort across media was uneven, and there was no examination of yearly seasonal variations. Within the EDA, those media sampled most extensively were soil, air, and sump water. Ground water was sampled less extensively and biota were sampled least often of any of the environmental media. Sampling in some media may have been inadequate to detect contamination.
- Too few replicate samples were collected per site to evaluate site variability; thus, the data on absolute concentrations of chemicals detected within any one region may not be meaningful.
- The study lacked adequate control area data; thus, comparisons among regions are difficult. However, as discussed more fully later, DHHS did not rely entirely on the control area data in its habitability decision.

The considerations outlined above apply to all the chemicals sought in the EPA monitoring study. However, OTA has examined the sampling situation for dioxin in greater detail because:

- dioxin is generally viewed as a very toxic material at very low concentrations,
- very high levels of dioxin were found in some locations within the EDA,
- public sensitivity to dioxin contamination is high, and
- it is possible to make some comparisons between the Love Canal dioxin sampling and that done by EPA recently in Missouri.

Monitoring for dioxin was insufficient with respect to extent (distribution), level, and replication. No conclusions can be drawn from the absence of positive findings for dioxin in most of the EDA. There can be little assurance that the findings accurately describe any contamination that could or could not exist there. Only 6 out of 21 environmental submedia in the EDA were sampled for dioxin; of the 10 regions in the EDA, only two were sampled for sump water contamination and three each for air and soil. In the 10 EDA regions no more than five sites were sampled per region, except for storm sewer sediment. No attempt was made to take replicate samples at all sites; this is particularly important because dioxin binds strongly to organic particles. Some further indication that sampling for dioxin in the EDA was inadequate is that in three Missouri sites the number of samples ranged from about 4 to 37 times more per acre than those used in the EDA.

3. The EPA monitoring study contains important uncertainties over the levels of the toxic chemicals detected, and the possible levels of those not detected. There are also uncertainties over possible synergistic human health effects of multiple toxic chemicals present at low concentrations. These two areas of uncertainty, as well as the lack of documentation by DHHS of its analysis, place the decision on habitability by DHHS in doubt.

The results of the EPA monitoring study were the major basis for the DHHS habitability decision. Two lines of evidence have been offered to support the view that the EDA is not too contaminated for habitation. DHHS has asserted that:

1. the EDA is no more contaminated than "control areas" near the EDA, and
2. the absolute levels of contamination are so low as to present no health threat.

OTA has not emphasized in this discussion a comparison of findings in the EDA with those in

the control areas used in the monitoring study. As discussed in the appendix, OTA's own analysis, analysis in other studies, and, to a degree, even EPA's own analysis disclose critical flaws in the study's use of control areas. As a result, most of the comparisons made between the EDA and control areas lack statistical confidence. In any case, DHHS maintains that its decision on habitability did not solely depend on making comparisons with the control areas.

Therefore, the following discussion focuses on the data which did form the critical basis of the DHHS decision—-the levels of contamination detected in the EDA. EPA has presented data to demonstrate that the low levels and the lack of patterns of contamination it found are consistent with levels found in industrialized areas nationwide. However, it is not clear how DHHS used this information.

Like others who have examined the results of the EPA monitoring study, OTA questioned the reliability of the study measurements, which found low values for most chemicals detected in the EDA; moreover 90 percent of all measurements found only trace amounts, or no detectable amounts, of contamination.

For the low values reported, the main issue is the validity of the values and the uncertainty that might exist in such values. EPA reported results as parts per billion (ppb) and did not report results as ppb plus or minus some value. The fact that "plus or minus" values are lacking means that the study provides no information on a possible spread in the detected levels. Such a spread could result from single or compounded errors in the entire chain of sampling, and analysis of the samples.

Closely related to this issue is the level of contamination which is judged to be significant to human health. Human health effects are different for different chemicals, and they are also different for the same chemical in different environmental media because of differences in exposure opportunities. For example, suppose that 100 ppb is the value, for a specific combination of chemical and environmental medium, below which health effects are not considered important or likely. In this case, a finding in a sample of 50 ppb plus or minus 10 ppb would be a firm basis for a decision that health is not likely to be affected. But if the result is 50 ppb plus or minus 40 or 50 ppb, then such a decision becomes much less certain. And in fact, it is often difficult to achieve high levels of certainty in associating a health effect with a given contamination level.

Considering the uncertainties in data and estimates of health effects, as well as in detection levels, the combination of the two introduces substantial uncertainty into a decision dependent on both. All technical data have some uncertainties; nevertheless policy decisions can make use of such data. The issue is: How much uncertainty exists? The uncertainties for the EDA monitoring data and with the health effects information used by DHHS are high, and they make policy decisions based on these technical inputs open to continuing debate.

EPA reported that its positive findings reliably indicated contamination in the EDA no higher than the low ppb range. NBS, which examined the EPA monitoring study to assess the adequacy of the analytical methodology, quality control and quality assurance programs, did not support the EPA contention. Based on a review of their analysis, OTA believes the NBS assessment is valid and has not duplicated it. NBS said:

> The methodology selected and used by EPA is appropriate for measuring concentrations in the low parts-per-billion range for air and water samples. However, *using appropriate methodology does not guarantee reliable results.* Thus, the question that remains is the level of performance of the laboratories conducting the analyses. At the low parts-per-billion level, *the contract laboratories displayed wide variability in performance.* Well-documented statements of precision and accuracy are critical since these provide the only valid basis for assessing the meaning of the numerical data to those who wish to draw their own conclusions from the report. Without such documented statements of precision and accuracy, the results of measurements are of limited usefulness for making comparisons within and among sites.[3] [Emphasis added.]

[3]From a letter by Raymond G. Kammer, Deputy Director, National Bureau of Standards, Aug. 30, 1982, sent to Senators Daniel P. Moynihan and Alfonse M. D'Amato and Congressman John J. LaFalce. This letter is the most recent statement from NBS and was written after EPA responded to the earlier comments of NBS, and also followed congressional hearings on the subject.

NBS also noted that the "limitations in the state-of-the-art for measuring biota and soils and sediments resulted in EPA appropriately focusing its study principally on air and water." What all this means is that there remains troubling uncertainty regarding the results of the monitoring study indicating low levels of contamination in the EDA. Some of the positive results said to be in the low ppb range may be as high as several hundred ppb because of variability and uncertainty. Of even greater uncertainty are the 90 percent of the results termed "not detected" or "trace." For these results, NBS continued, in the letter quoted from above:

> Unless measured values, including "none detected," are accompanied by estimates of uncertainty, they are incomplete and of limited usefulness for further interpretation and for drawing conclusions. For these reasons, performance " . . . in the low parts-per-billion range" has not been demonstrated to our satisfaction in the documentation.
>
> Based on knowledge of the analytical methodology used by EPA and the documentation provided by EPA, NBS has no reason to believe that measurements labeled "none detected" or "trace" represent concentrations above one part-per-million. [Emphasis added.]

DHHS has taken the results of the EPA monitoring study, including EPA's reply to NBS concerns, to mean that the chemicals present in the EDA are present in amounts ranging from low ppb to perhaps several hundreds of ppb. Furthermore, except for the locations in which high levels of contamination, primarily dioxin, were found, DHHS has made the judgment that less than 1-part-per-million levels support a positive finding of habitability; i.e., that contamination is for the most part so low and so unexceptional as to rule out possible health effects for those choosing to reside in the EDA.

OTA believes that the persistent concerns of NBS remain valid. EPA has not yet provided all the considerable details of its monitoring study that would permit outside experts to reach EPA's own level of confidence in its data. Thus, levels of contamination may or may not be consistently as low as DHHS concludes, and as EPA assures them to be. Moreover, OTA has had difficulty in assessing the foundation for the DHHS decision, as few details have been released (e.g., what health effects data for specific chemicals and environmental media were considered, and how these were linked to specific results of the EPA monitoring study). DHHS faced problems with EPA's monitoring study because details were absent from the publicly available documentation. Ironically, this is now the case with materials made available by DHHS.

DHHS has not explained how it considered the potential for synergistic health effects from the many toxic chemicals at Love Canal. Synergism means that low levels of contamination for several chemicals may combine to pose health threats, even though the same chemicals present individually at the same low levels of contamination might not be considered threatening. This comment should not be interpreted to mean that much information on possible synergistic effects exists. Unfortunately, there are few data on synergistic effects for the many toxic chemicals which may contaminate the EDA. However, this lack of information contributes to uncertainty for possible health effects. The importance of this uncertainty to DHHS is not clear.

It is also possible that for a few chemicals (e.g., hexachlorobenzene), contamination at levels of only hundreds of parts per billion may pose health threats. Such levels, because of uncertainties, may have been present in samples recorded as having no detectable or trace amounts. Of particular concern is uncertainty about the "no detect" results for some two-thirds of samples tested for dioxin. First, the number of samples tested for dioxin was very small, only four soil samples in the entire EDA of over 200 acres were taken. Moreover, the problems of analyzing for dioxin are well known. They may have been less known and, perhaps, even worse in 1980 than they are today.

Finally, the semantics and logic of the formulation of the habitability issue raise questions. So do the statements by DHHS on its habitability decision. DHHS defined the task for itself and its consultants in this way:

> Based on available data, can it be concluded that the area is not habitable?[4]

This formulation of the habitability decision task seems to demand one of two answers: either the EDA is to be demonstrated as unsafe or it is habitable.* In light of this formulation, DHHS summarized its interpretation of the findings of the panel of 11 outside experts who advised DHHS staff, as follows:

> . . . a majority of the consultants concluded that based on the data available they could not conclude that the area was not habitable.[5]

However, as indicated earlier, the inability to conclude that the EDA is not habitable does not necessarily imply that the EDA is habitable. It may be questioned whether the findings of the DHHS panel of consultants, as quoted above, support the statements DHHS ultimately made on habitability.

The most recent statement on habitability, by a senior member of the DHHS team that made the original habitability decision, includes no reference to control areas and is put in unusually positive terms:

> Review of these [monitoring] data by the Department of Health and Human Services, with evaluation of technical methodologies by the National Bureau of Standards, led to federal recommendations in July 1982 that the general area surrounding the Love Canal was safe for human residence outside the canal itself and the two rings of homes surrounding it. It was also recommended that the storm sewers and their drainage tracts be cleaned and that special plans be made for perpetual maintenance of the clay cap covering the site.[6]

Relative to our earlier expressed concerns regarding cleanup and maintenance of the site, this statement lacks the strong contingency element of the original DHHS statement on habitability. Instead, it poses cleanup and maintenance needs as separate from the habitability conclusion. It provides less assurance that the site will in fact be cleaned up and the cleanup maintained; a concern which is emphasized in the OTA analysis.

Heath of DHHS notes that "one would hope that this could be done while restoring the surrounding neighborhood to normal activity." This rather general statement not only retreats from the implication that cleanup is a prerequisite to habitability, it fails to address the potential problems of cleaning up the locations contaminated with high dioxin levels without threatening the health of nearby residents.

The results of studies on health effects and chromosomal damage in Love Canal area residents may appear relevant to the DHHS habitability decision. For the most part, these studies have found little positive evidence of health damage. However, the following conclusion and caveat by Heath should be noted:

> . . . it can be said from current epidemiologic data available at Love Canal that no striking increases in illness occurrence have thus far appeared in association with living near the canal. This does not mean that such occurrences might not yet appear or that some canal-related illness may not have occurred but at frequency levels not detectable by the studies performed.

The present state of uncertainty about health effects for Love Canal area residents is not unique. It is common. That is why so much public policy in the environmental protection area is precautionary in nature. To wait for conclusive evidence for adverse health effects in people would mean that people could be unnecessarily exposed to toxic chemicals.

4. OTA's analysis of some of the data obtained in the EPA monitoring study provides limited, but not conclusive, indication that there may be contamination in the EDA by toxic chemicals from Love Canal.

[4]Statement of Edward N. Brandt, Assistant Secretary for Health, Department of Health and Human Services, hearing of Subcommittee on Commerce, Transportation, and Tourism, House Committee on Energy and Commerce, Aug. 9, 1982.

*This formulation of the problem might be interpreted differently; i.e., that it demands a lesser burden of proof than a formulation which begins with the premise that the area is unsafe. Detecting contamination is, at least theoretically, easier than proving that an area is free of contamination. However, this is only the case if there is precise design of the study and use of procedures which yield low levels of uncertainties for experimental results.

[5]Brandt, op. cit.

[6]Clark W. Heath, "Assessment of Health Risks at Love Canal," *Fourth Annual Symposium on Environmental Epidemiology*, May 2-4, 1983, Pittsburgh, Pa. (Dr. Heath was the senior author of the DHHS habitability statement in July 1982.)

Despite the limits and uncertainties of EPA's monitoring study previously discussed, OTA considered the possibility that the positive detections found might be analyzed so as to better discern whether significant contamination existed in the EDA. Although some interesting, suggestive results were obtained regarding contamination of the EDA, by no means are these results strong enough to support a conclusion of nonhabitability. The results also suggest how future monitoring studies may be designed to produce more certain results.

OTA disaggregated the EPA monitoring data to allow an examination of a small universe of data, what we term "indicator compounds." These are toxic chemicals which are known to have been disposed of in Love Canal and which the monitoring study looked for in the control areas and the EDA. A statistical analysis was performed for OTA to determine whether any observed differences in detections of contaminants in the EDA as compared to the control areas were statistically significant. Four chemicals (1,2- and 1,3-dichlorobenzene and 2- and 4-chlorotoluene) were found to be present in the EDA at significantly greater frequencies than in the control areas. However, the levels found for these chemicals were quite low.

Why was it possible for OTA to find these statistically significant differences between detection of contaminants in the EDA versus the control areas when EPA came to a general conclusion that the EDA was not significantly more contaminated than the control areas? The chief answer is that OTA combined monitoring data for all environmental media tested, thereby enlarging the data base per chemical. EPA analyzed data per chemical for each submedia tested, which meant that there were very few data for the control areas. In this situation there were too few data from the control areas to reveal statistically significant differences with the EDA. However, for several chemicals EPA did find several significantly higher frequencies of detection in the EDA samples as compared to the control areas. Essentially, EPA discounted the few positive findings of significantly more frequent contamination in the EDA because the number of negative findings was far larger. This preponderance of negative findings was based on the large number of chemicals which EPA monitored in the study—about 150 chemicals, including 129 which are considered to be "priority" pollutants for general regulatory purposes but, by and large, have no history of disposal in Love Canal. *In other words, with regard to its analysis and interpretation of data, EPA directed a substantial portion of its efforts toward chemicals that are not necessarily unique and important in the Love Canal situation.*

POSSIBLE STEPS TOWARD REHABITATION

In making decisions on the habitability of the EDA, there are choices other than immediate, complete rehabitation and a continued presumption against people moving back into the area. A number of actions could be taken to move toward incremental rehabitation of the EDA. By incremental rehabitation we mean a paced, cautious approach resting on improvements in the scientific certainty for conclusions about the safety of the EDA, and on increased public confidence in policy decisions based on technically complex data and analyses. Habitability need not be seen "as an all or nothing" issue.

In fact, one of the difficulties in assessing the habitability of the EDA, which the EPA monitoring study unfortunately did not resolve, is that some portions may not be contaminated, while others *may* be. Over time, portions of the EDA may be found, with a higher degree of confidence, to be free of contamination. Depending on their location, they may then be judged habitable. One complexity is that if some areas are found to be contaminated, then it will be necessary to clean them up and to assess the effect of the cleanup actions on uncontaminated and, perhaps, rehabitated areas.

Four critical actions merit further consideration:

1. The technical problems and uncertainties in the current cleanup activities and long-term

plans for operation and maintenance of the containment system should be removed. There must be effective cleanup of areas known to be contaminated with dioxin.

2. The uncertainties of institutional stability and effectiveness over very long terms (i.e., hundreds of years) should be addressed. There may be ways to assure that the funds necessary for indefinite monitoring, operation and maintenance of the containment system, and for possible corrective actions, will be available over the long term. It may be possible to remove uncertainties related to the ownership, title, and future use of Love Canal. There are probably ways to assure that critical information is retained and made accessible over long periods.
3. It should be possible to design well-focused monitoring studies to be conducted for carefully defined areas of the EDA, perhaps for individual homesites. To some extent, the EPA's 1980 monitoring study can serve a function similar to that of a pilot study. The new studies could monitor for fewer chemicals, sampling can be improved, and analytical results can be presented in ways that remove uncertainties over their reliability and accuracy. Costs are a concern, but may prove to be a reasonable investment. It appears that additional monitoring for individual homesites (including several samples for dioxin and multiple samples for chemicals known to have been deposited in Love Canal) might have a one-time cost of about $5,000 per site.
4. Finding a permanent solution for the large amounts of long-lasting toxic wastes still in Love Canal is highly desirable. The present containment approach may best be viewed as an interim solution. Plans could be made to:
   - track technological developments for permanently destroying or detoxifying the wastes, and
   - assess the technical feasibility and economic cost effectiveness of applying such developments at Love Canal.

Finally, EPA should provide considerably greater detail on the results of its monitoring study, which might resolve the uncertainties raised by NBS in its examination of currently available documentation.

IMPLICATIONS FOR THE SUPERFUND PROGRAM

This case study provides insights into several issues involved in the Federal Superfund program for cleaning up uncontrolled hazardous waste sites.

1. The "How Clean Is Clean?" Issue

Technical standards to determine unacceptable levels of contamination by toxic chemicals are, on the whole, lacking. Some standards do exist in various environmental programs, but there is no overall set of standards for the broad range of toxic chemicals associated with hazardous wastes. Having such standards, however, does not rule out the use of site-specific information (e.g., concerning migration routes and potential exposure levels) to arrive at habitability decisions.

Without standards, Government agencies must make ad hoc decisions. Uniform protection nationwide is unlikely, and decisions may not always be technically valid. This Love Canal case study illustrates three uses for standards for acceptable (and unacceptable) levels of contaminants:

- With such standards, technical information on contamination, even if only from pilot or preliminary monitoring, could provide the basis for decisions on relocation of residents and the nonhabitability of areas.
- Standards could be very useful in designing detailed monitoring studies to assess the full extent and level of contamination. The problem could be defined as assuring that stand-

ards are not exceeded, rather than detecting anything that might be present. Interpretation of the results of monitoring studies would also be improved. Standards would probably make the use of control areas unnecessary.

- The choice of cleanup technologies could be more effective, if based on standards that set targets and goals for the cleanup action.

2. Health Effects Data and Decisions on Habitability

Better understanding of the health effects of toxic chemicals is a critical need, particularly on the various exposure routes for toxic chemicals in hazardous waste sites. Using available data, it is possible to establish some standards for acceptable levels of contamination, but more data are needed to establish more reliable and complete standards. Health effects data can be collected from conventional research, but more effective implementation of the congressional mandate in the Superfund legislation is also needed to expand the epidemiological data base for health effects in people already exposed to toxic chemicals. Moreover, policy decisions on evacuation and relocation of residents, and on (re)habitability, need a firmer underpinning of administrative and analytic procedures. The responsibility given to DHHS for the Love Canal EDA was not very clearly defined in this respect. For example, no detailed analysis supporting the DHHS decision was provided. The role of EPA relative to DHHS in substantiating and reaching habitability decisions, and perhaps the use of consultants and advisory panels by DHHS, needs further examination. In the case of Love Canal, interactions between EPA and DHHS that could have influenced the design and implementation of the monitoring study were not possible because DHHS did not play a role until after the study was completed. If DHHS is to continue to be responsible for decisions on relocation and habitability, then it may be appropriate for it to participate more actively in the design and implementation of monitoring studies, and the analysis of their results.

3. Technical Guidelines for Monitoring Studies

The entire experience in the EDA monitoring program underlines the need to develop appropriate sampling and analytical protocols for a number of toxic chemicals and environmental media. It is also highly desirable to establish requirements for the presentation and documentation of results of monitoring studies, including estimates of error and uncertainty.

4. Selection and Implementation of Remediation Programs

A very important implication of this case study for the Superfund program concerns the statutorily required analysis of alternative cleanup approaches. At Love Canal, and apparently at many other Superfund sites, there has been no detailed consideration of permanent solutions. The cost-effectiveness study of which cleanup methods to use at Love Canal considered alternatives for isolating or containing the hazardous wastes in the canal, but none that would destroy or detoxify the wastes. Methods to accurately evaluate the relative cost effectiveness of containment versus permanent solutions require more study.

The containment method adopted imposes operating and maintenance costs for all time (presumably for which New York State is responsible). It is also subject to technical uncertainties about possible future failures and release of toxic substances into the environment.

This leads to an exceptionally important consequence of the Love Canal experience for the Superfund program: the need to compel consideration of more permanent solutions, albeit with higher capital costs (to be paid mostly by the Superfund program), in analyses of alternative cleanup approaches. Some technical approaches for onsite destruction and detoxification of toxic wastes and contaminated materials are available today, and considerable effort is going into the development of more such techniques. Even if a permanent solution does not appear technically or economically feasible for a specific site at the

outset, there is a need for a formal, continuing program to evaluate relevant scientific research and developing technological opportunities for such permanent solutions, site by site. The growing trend to relocate residents away from critical uncontrolled waste sites, followed by containment of wastes and contaminated materials, means continuing difficulties in establishing long-term safety for rehabitation.

Another apparent need is for improved oversight by EPA of State implementation of selected remediation programs. In the case of the EDA, the delay in cleaning up areas known to be highly contaminated with dioxin—still not carried out several years after its discovery—is disturbing. However, New York State has faced a number of critical tasks at Love Canal as well as at other uncontrolled hazardous waste sites that have undoubtedly strained its resources.

5. Long-Term Institutional Capabilities and Issues

Love Canal may have yet another unique and useful historical role. Some Government regulations recognize the long-term hazards of nuclear wastes and, reflecting concern for future generations, impose requirements for assured isolation over thousands of years. Yet there has been very little attention to the long-term hazards of toxic wastes, and the extreme uncertainties of containment approaches for controlling them. This neglect is paradoxical and inconsistent. Many of the most toxic wastes will retain their hazardous characteristics indefinitely. Unlike nuclear wastes, most such toxic wastes (molecules) have no inherent half-lives; i.e., they will remain stable unless they degrade through environmental interactions. Yet Government regulations for new land disposal facilities have well-defined requirements extending only 30 years. In addition, the Superfund program has given no consideration to the capability of institutions to carry out essential tasks of controlling toxic waste sites for hundreds or thousands of years.

In considering the long-term effectiveness of the current remediation plan for the EDA, it became apparent that there are currently no mechanisms to assure indefinite funding for monitoring, for operation and maintenance, and possibly for corrective actions for the waste containment system at Love Canal. Considering the recent failures of many public and private institutions to control toxic wastes adequately, it is unreasonable to expect the public to have confidence in a Superfund program that makes extensive use of long-term waste containment but provides no assurances for the long-term effectiveness of those "solutions."

It is likely that waste containment at Superfund sites will continue to be used until there are more widely available and low-cost technological alternatives to destroy or detoxify wastes and contaminated materials onsite. The issues of long-term institutional effectiveness cannot be escaped.

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Appendixes

Appendix A
Remediation

Summary

There are four areas of uncertainty that can affect projections of the long-term integrity of the remedial technology. Before any decision on habitability can be made, these uncertainties must be addressed and solutions identified.

1. **Remedial Action in the Emergency Declaration Area (EDA).**—The areas in the EDA contaminated with high levels of dioxin have not yet been cleaned up. Moreover, until just a few months ago storm sewers leading from the canal region to the EDA and known to contain dioxin remained open. It is possible that during the past few years—after completion of the EPA monitoring study—dioxin may have been transported within or beyond the EDA. A study to determine the full extent of contamination in and near the sewers is not completed.

2. **Leak Detection Systems.**—The long-term integrity of the remedial technology is not certain. Reliable methods are needed to allow detection of damage (leading to permeability) to the two basic elements of the containment system. These elements, intended to minimize water entering the canal, are the cap over the canal area and the concrete barrier wall to be built around it. There is no dispute about the need for repair and replacement of the cap and leachate collection system over time. Yet how it will be done is not clear. How structural damage or clogging of the drain system will be detected, and how repair and replacement can be carried out safely remain unanswered.

3. **Monitoring Programs.**—Assurance of sufficient warning about any potential migration and accumulation of chemicals from the canal is essential. Plans are underway for developing a long-term monitoring plan for ground water in the area immediately adjacent to the canal but not in the EDA. It is also necessary to design more extensive ambient monitoring of environmental media other than ground water (e.g., air, soil, and biota). Media other than ground water are possible routes of exposure to toxic chemicals. For example, depending on the properties of chemicals disposed in the canal and properties of the soil through which the ground water moves, some chemicals could be filtered out and could accumulate in soil or possibly in biota. Humans might become exposed to either. In addition, damage to the cap could allow release of volatile compounds into the air.

4. **Institutional Mechanisms for Long-Term Protection of the EDA Residents.**—The fourth major area of uncertainty concerns the long-term ability of government institutions to remember, fund, and carry out commitments for long-term continued monitoring and maintenance of the site. The full range of institutional issues surrounding very long-term commitments for managing uncontrolled hazardous waste sites under the Superfund program have not been addressed. Current cost estimates for routine operation, maintenance, and replacement of the leachate collection system are about $0.4 million now, $4.2 million in the year 2005, and $8.5 million in 2030. There is no guarantee that State officials 20 or 100 years from now will either remember or honor this commitment. Furthermore, there are few institutional mechanisms in place to assure continuity in transferring vital information on Love Canal from one generation to the next. Nor does it appear that New York State has taken unequivocal, binding, and permanent title of the canal area in a manner that prevents future use of the site.

Categories of Remedial Technology

Technical options for remedial action implemented under the authority of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) can be categorized as either waste control or environment control.[1] Table A-1 lists the types of technologies in these two categories and illustrates some of the advantages and disadvantages of each. The implementation of any of them will depend on site-specific conditions. In some situations, a combination of waste and environment control strategies would be required.

Waste control refers to the removal of the hazardous material from a site, followed by some treatment that reduces the potential harm of hazardous compounds and subsequent disposal of the waste or treatment residue in an appropriate facility. The treatment can involve destruction of toxic components of the excavated material through chemical, physical or biological processes, or immobilization of the hazardous components.

At present, the application of destruction techniques has been limited to excavated materials or small area spills treated by biodegradation and chemical processes. Some thermal destruction technologies are available. Thermal destruction of large volumes of contaminated material, such as excavated soil, is a new ap-

[1] *Technologies and Management Strategies for Hazardous Waste Control*, "Chapter: Technologies for Hazardous Waste Management: Uncontrolled Sites" (Washington, D.C.: U.S. Congress. Office of Technology Assessment, OTA-M-196, March 1983).

Table A-1.—Advantages and Disadvantages of Control Technologies

Type	Advantages	Disadvantages
Waste control technologies:		
Excavation and removal followed by treatment or disposal	• Good for containerized or bulk disposal	• High initial costs • Potential higher risk during cleanup • Relocation of risk unless waste is treated • Not cost effective for low level hazardous waste or uncontainerized buried waste in large area
Excavation with onsite treatment	• Expose waste to complete treatment	• High initial cost • Difficult to assure monitoring effectiveness • Some risk of exposure • Not cost effective for large amount of low-hazard waste
Neutralization/stabilization	• Useful in areas where waste excavated prior to mixing • Low risk of exposure if injection method is used	• Limited application • Requires long-term land use regulations • Eventual offsite migration if reaction is incomplete
Biodegradation	• Low costs	• Difficult to maintain optimum conditions to keep reaction going
Solution mining	• Useful in homogeneous uncontainerized solvent-soluble, buried solid hazardous waste	• Can result in uncontrolled release
Environmental control:		
Isolation, containment, and encapsulation	• Useful for large volumes of mixed hazardous and domestic waste and low-hazard waste	• Effectiveness depends on physical conditions • Long-term O&M needed
Ground water diversion and recovery	• Useful if soils are permeable or if there are high perched water tables	• Requires wastewater treatment option • Process is slow • O&M monitoring • Not effective for insoluble or containerized material
Surface water diversion	• Easy to implement • No transport of waste offsite	• Can create flooding offsite
Ground and surface water treatment	• Can be used onsite or offsite	• May generate hazardous sludges, spent carbon • Long-term monitoring
Gas collection or venting	• Low costs	• Site safety and fire hazards • Offsite air pollution • Long-term monitoring and O&M

O&M—operating and maintenance.

SOURCE: Office of Technology Assessment, op. cit., p. 210.

plication and data on its efficiency are limited. Thus, these technologies currently have not received widespread consideration as a remedial technology.

An alternative to destruction is the immobilization of hazardous components. This is achieved by encapsulating the excavated material in some impermeable matrix. When placed in soil or marine environments, migration of hazardous constituents is then prevented (or at a minimum, the rate of migration is decreased); thus, the risk to public health and the environment is reduced.

These control technologies can be used effectively when the waste has been deposited in containers and removal from the site can be accomplished readily. It also can be implemented at those sites where hazardous components have not become distributed throughout environmental media. For example, it is used at those sites where bulk disposal has occurred and *before*

widespread migration of the material within the soil has taken place. However, if the contaminated area is large, e.g., measured in several acres, waste control techniques are difficult and costly to implement.

In the case of an accidental spill, removal and subsequent treatment can be effective, if remedial action is not delayed and boundaries of the spill can be identified easily. Under appropriate site conditions, treatment techniques can be used without removal of the contaminated material, e.g., in situ biological or chemical degradation of soil contaminated through an accidental spill of hazardous chemicals.

Environment control options include those techniques that contain or isolate hazardous material, divert water movement away from a site, or treat contaminated water sources. A review of 23 landfill sites suggests that environment control is the more common remedial strategy currently in use.[2] The technologies for containment are not new; rather they are adapted from structural or civil engineering procedures and consist of the installation of caps, barrier walls, and drainage systems.[3] [4] At many sites, containment technology is used in combination with water diversion techniques. These latter include changing the flow of surface water to prevent flow into a contaminated site or removal and treatment of ground water that has been contaminated.

Because the strategy of environment control does not remove sources of contamination, it is necessary to include safeguards that increase the likelihood of long-term integrity of containment and reduce effects of failure should it occur. Well-developed environmental monitoring programs are essential safeguards. Monitoring should include all environmental media: water, air, soil, and biota. Moreover, some sort of leak detection system is necessary to warn of possible release of contaminants through the natural or synthetic barriers of the containment structure.

When comparing these two categories of remedial technology, *advantages and limitations* can be identified. For example, environment control offers certain advantages over waste control in that large areas of contamination (e.g., many acres) can be controlled. In addition, installation costs are generally less for environment control technologies than for waste control. Environment control technologies eliminate the potential transfer of risk from one area to another; for some waste control options this transfer of risk is a major consideration. Moreover the use of environment control technologies does not create risks for transportation accidents. Environment control, however, requires long-term (i.e., forever) operation and maintenance. In contrast, waste control includes treatments that completely destroy the hazardous material, eliminating long-term hazards. Both environment control and those waste control options that only immobilize hazardous components must include long-term monitoring programs.

A major concern associated with either type of remedial action is the limited experience with these techniques. Sites using either waste or environment control have not been in existence long enough to provide sufficient data about the long-term integrity of the methods. For example, a review of sites where environment control has been in place indicates that the "oldest site" has had a clay barrier wall (5- to 8-ft thick) only since 1976.[5] Monitoring at this site has not yet indicated leakage through the wall. Remediation at the oldest sites incorporating barrier systems using synthetic materials (e.g., asphalt-bentonite, cement-bentonite) were completed only in 1979.[6] Thus, our experience regarding long-term integrity of containment technology is limited.

Uncertainties exist for waste control options, also. Unless the extent of contamination can be characterized in detail, i.e., the types and concentrations of all constituents are known, complete destruction of hazardous elements cannot be validated. New constituents could be formed as products of the biological, chemical, or thermal processes taking place. These new constituents could be as, or more hazardous than, the original compounds.

Much theoretical work has been done to predict the performance of remedial technology. While the information gained through the use of theory and models is important, it must be emphasized that at present *no field experience exists.* The persistence of many waste constituents is much longer than the effective lifetime of the environment control technologies; the degree of hazard for components in wastes may be increased by waste control treatments. Thus, environment control may simply postpone risks to public health and the environment to future generations, and waste control may create new hazards.

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[2]E. Nagle, Environmental Law Institute, personal communication, April 1983.

[3]C. Kufs, et al., "Alternatives to Ground Water Pumping for Controlling Hazardous Waste Leachates," *Management of Uncontrolled Hazardous Waste Sites*, Hazardous Materials Control Research Institute, 1982, pp. 146-149.

[4]P. A. Spooner, R. S. Wetzel, and W. E. Grube, "Pollution Migration Cutoff Using Slurry Trench Construction," *Management of Uncontrolled Hazardous Waste Sites, Hazardous Materials Control Research Institute, 1982, pp. 191-197.*

[5]*Nagle, op. cit.*

[6]*Ibid.*

Evaluation of Alternative Technologies at Love Canal

In accordance with CERCLA requirements, EPA did a cost-effectiveness analysis of alternative technologies for remedial action at Love Canal. Their analysis considered only environment control technologies. OTA identified factors that are relevant to consideration of waste control options:

1. Given the large area of the landfill and adjacent land, waste control technologies likely would be costly, possibly greater than environment control by orders of magnitude. For example, excavating *and treating* 49 acres of contaminated soil to a depth of possibly 15 ft (equal to nearly 2 million tons of contaminated soil) would be a major and expensive task with current technologies, particularly in water saturated zones.
2. Workers as well as residents in the EDA would be exposed to hazardous substances through the excavation process and formation of potentially hazardous products by operation of a waste treatment system.
3. Given the broad range of chemicals that were originally dumped in the canal and the variety of products that could result from natural and enhanced degradation as well as thermal combustion processes, the outcome of destruction efforts is uncertain with present technology. Demonstration studies would be required to evaluate the efficacy of the waste control treatments. These studies would delay completion of remedial action and possibly increase the risk to residents remaining in the EDA.
4. The problem of finding an ultimate disposal site for treatment residue would be difficult to resolve without knowing its hazardous quality. Disposal of such residues in a new site could result in merely relocating health and environmental risks.

The environment control alternatives considered by EPA included four alternatives:[7]

1. No additional action beyond operation and maintenance of a leachate collection system.
2. Cut-off and plugging utility lines, in addition to alternative 1. All utility conduits that are possible routes for lateral movement from the site would be plugged and all utility lines beyond the containment areas would be cleaned.
3. Alternatives 1 and 2, plus installation of a partial wall. A subsurface wall would be installed at points of natural migration routes from the site—e.g., sand lens or drainage swales.
4. Alternatives 1 and 2, plus complete containment of the contaminated area. Construction of a barrier wall that would completely enclose the site.

A summary of the lifecycle costs for these alternatives is presented in table A-2. Although initially the costs are greatest for option 4, over a period of 50 to 200 years this alternative is expected to result in the lowest total cost to the State. As indicated in table A-3, each alternative was also evaluated based on expected performance. Alternative 4 provides the greatest relative protection for public health and the environment.

Table A-2.—Summary of Lifecycle Costs
(present worth in 1981 dollars—1 $\times 10^6$)

	1 year	50 years	100 years	200 years
Alternative 1:				
Capital	—	—	—	—
O&M	0.25	12.73	25.46	50.92
Replacement	—	1.04	7.29	20.19
Total	0.25	13.77	32.75	71.11
Alternative 2:				
Capital	0.61	0.61	0.61	0.61
O&M	0.25	12.73	25.46	50.92
Replacement	—	1.04	7.29	20.19
Total	0.86	14.38	33.36	71.72
Alternative 3:				
Capital	1.99	1.99	1.99	1.99
O&M	0.20	10.09	20.17	40.34
Replacement	—	0.79	8.17	22.02
Total	2.19	12.87	30.33	64.35
Alternative 4:				
Capital	2.55	2.55	2.55	2.55
O&M	0.14	7.02	14.04	28.08
Replacement	—	1.49	1.49	21.35
Total	2.69	11.06	18.08	51.98

NOTE: Alternative 1—No additional action beyond installation of leachate collection system.
Alternative 2—Utility cut-off containment.
Alternative 3—Partial slurry wall containment.
Alternative 4—Complete slurry wall containment.

SOURCE: CH$_2$M-Hill, op. cit.

When Congress included the requirement of conducting cost-effective analyses in the Superfund legislation, the intent was that both waste and environment control alternatives would be considered. While it is apparent that alternative 4 is preferred over alternatives 1 through 3, OTA questions the omission of some consideration for of any waste control technology in the cost-effectiveness analysis. As indicated above, present waste control technology cannot handle efficiently the large volumes of contaminated material that exist at the Love Canal site. Therefore, choosing environmental control options makes sense

[7] *CH$_2$M-Hill, Immediate Remedial Action-Uncontrolled Hazardous Waste Disposal Sites, Zone 1, preliminary draft report for U.S. EPA Region II, April 1982.*

Table A-3.—Performance Criteria Evaluation

Criterion	Rank[a b c] Alt. 1	Alt. 2	Alt. 3	Alt. 4
Initial cost	1	2	3	4
O&M cost	3	3	2	1
Lifecycle cost	3	4	2	1
Long-term environmental impact	4	3	2	1
Short-term environmental impact	1	2	3	4
Construction site health and safety	1	2	3	4
Community health and safety	4	3	2	1
Technical reliability	1	2	2	2
System reliability	4	3	2	1
Community acceptance	4	3	2	1
Construction duration	1	2	3	3
Achieve objectives	4	3	2	1
Meet project bid date	1	2	2	2

[a]Ranking ranges from "1" = best to "4" = worst. Equal rankings denoted by equal low numbers.
[b]Alternative 1 = No additional action beyond leachate collection system.
Alternative 2 = Utility cut-off containment.
Alternative 3 = Partial slurry wall containment.
Alternative 4 = Complete slurry wall containment.
[c]No weighting factors have been applied to performance criteria.

SOURCE: CH2M-Hill, op. cit.

as a short to medium term action, pending development of technology to deal permanently with the material. However, *environment control cannot and should not be considered a long-term or permanent solution.*

Many people have cited the great uncertainty of assuring long-term protection using environment control technologies. No effective alternative has been advanced. New York State officials are convinced that greater efforts should be expended on research and development of detoxification and destruction techniques thus, eliminating the need for long-term commitments to protection of a large land area. Once these technologies have been developed, they must be given serious consideration in any cost-effectiveness analyses for remedial technology. Although waste control options might be extremely costly to implement, it is possible that these would compare favorably with total costs over a 200-year time period for environment control options. In addition, the complete elimination of the hazard due to waste control treatments may outweigh objections to the high cost for implementing this type of remedial action and the short-term risks to workers and residents due to excavation of the material.

Control Action at the Love Canal Site

Because of the large area involved and environmental distribution of wastes disposed in the canal, the remedial action chosen by EPA and the New York State Department of Environmental Conservation (NYS/DEC) follows a strategy of environment control. Two types of technologies are used: a leachate collection system, for which construction began in 1978; and a containment system, for which construction work was planned for June 1983. These technologies are commonly used for remedial action.[8 9 10]

The *drainage system* became operational in 1979 and is to continue indefinitely with planned repair and replacement. The system consists of a clay cap covering the immediate area of the original landfill; a French drain system rings the cap enclosing an area of approximately 23 acres.

Ground water migrates through the site into the drainage system, is pumped into an onsite treatment facility, and put into clarification tanks where water and sludge phases are separated. The average flow through the system is 8 gallons per minute (gpm); the maximum capacity is 200 gpm and peak flows of 48 gpm have been recorded during the wet season.[11] The water phase is drawn through an activated carbon system and effluent discharged into the municipal sewage system.

Effluent standards have been established by the City of Niagara Falls specifically for discharge of effluent from this facility. For every day that the treatment facility is operational, analyses are performed to determine whether these standards are being met. Analyses include tests for the presence of priority pollutants (see table A-4) determination of effluent pH levels (the effluent is neutral), and analyses of levels of total organic carbons (tests the efficiency of the activated carbon system), and total chlorinated hydrocarbons. A review of available data on constituent levels within treated leachate indicates that the *highest value* recorded for any of the priority pollutants was 46 parts per billion (ppb).[12] Even this low concentration has been detected only occasionally; most results of the analyses indicate no detection. State and city officials consider values in the ppb range to be sufficiently low because the effluent receives further treatment in the public wastewater treatment system.[13] Residues from the treatment

[8]*Spooner, Wetzel, and Grube, op. cit.*
[9]*J. C. Evans and H. Fang, "Geotechnical Aspects of the Design and Construction of Waste Containment Systems," Management of Uncontrolled Hazardous Waste Sites,* Hazardous Materials Control Research Institute, 1982.
[10]*Handbook for Remedial Action at Waste Disposal Sites* (Washington, D.C.: U.S. EPA Municipal Environmental Research Laboratory, EPA-625/6-82-006, June 1982).
[11]CH2M-Hill, op. cit., p. 3-1.
[12]W. J. McDougall, R. A. Fusco, and R. P. O'Brien, "Containment and Treatment of the Love Canal Landfill Leachate," *Journal WPCF,* vol. 52, No. 12, 1980, pp. 2,914-2,924.
[13]N. Kolak, New York State Department of Environmental Conservation, personal communication, March 1983.

Table A-4.—Priority Pollutants

Volatile organic compounds
Acrolein
Acrylonitrile
Benzene
Carbontetrachloride
Chlorobenzene
1,1-Dichloroethane
1,2-Dichloroethane
1,1,1-Trichloroethane
1,1,2-Trichloroethane
1,1,2-2-Tetrachloroethane
Chloroethane
2-Chloroethylvinyl ether
Chloroform
1,1-Dichloroethylene
1,2-Trans-dichloroethylene
1,2-Dichloropropane
1,3-Dichloropropene
Ethylbenzene
Methylene chloride
Methyl chloride
Methyl bromide
Bromoform
Dichlorobromomethane
Trichlorofluoromethane
Chlorodibromomethane
Tetrachloroethylene
Toluene
Trichloroethylene
Vinyl chloride
Bis (chloromethyl) ether

Base-neutral extractable organic compounds
Acenaphthene
Benzidine
1,2,4-Trichlorobenzene
Hexachlorobenzene
Hexachloroethane
Bis (2-chloroethyl) ether
2-Chloronaphthalene
1,2-Dichlorobenzene
1,3-Dichlorobenzene
1,4-Dichlorobenzene
3,3'-Dichlorobenzidine
2,4-Dinitrotoluene
2,6-Dinitrotoluene
1,2-Diphenylhydrazine
Fluoranthene
4-Chlorophenyl phenyl ether
4-Bromophenyl phenyl ether
Bis (2-chloroisopropyl) ether
Bis (2-chloroethoxy) methane
Hexachlorobutadiene
Hexachlorocyclopentadiene
Isophorone
Naphthalene
Nitrobenzene
N-nitrosodimethylamine
N-nitrosodiphenylamine
N-nitrosodi-n-propylamine
Butyl benzyl phthalate
Di-n-butyl phthalate
Di-n-octyl phthalate
Diethyl phthalate
Dimethyl phthalate
Benzo(a)anthracene
Benzo(a)pyrene
3,4-Benzofluoranthene
Benzo(k)fluorathene
Chrysene
Acenaphthylene
Anthracene
Benzo(ghi)perylene
Fluorene
Phenanthrene
Dibenzo(a,h)anthracene
Ideno(1,2,3-cd)pyrene
Pyrene
Bis (2-ethylhexyl) phthalate

Acid extractable organic compounds
2,4,6-Trichlorophenol
Parachlorometa cresol
2-Chlorophenol
2-Nitrophenol
Pentachlorophenol
2,4-Dimethyphenol
4-Nitrophenol
2,4-Dinitrophenol
4,6-Dinitro-o-cresol
2,4-Dichlorophenol
Phenol

Pesticides and PCBs
Aldrin
Dieldrin
Chlordane
4,4'-DDT
4,4'-DDE
4,4'-DDD
a-Endosulfan
b-Endosulfan
Endosulfan sulfate
Endrin
Endrin aldehyde
Heptachlor
Heptachlor epoxide
a-BHC
b-BHC
q-BHC
w-BHC
PCB-1242
PCB-1254
PCB-1221
PCB-1232
PCB-1248
PCB-1260
PCB-1016
Toxaphene
2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD)

Metals
Antimony
Arsenic
Beryllium
Cadmium
Chromium
Copper
Lead
Mercury
Nickel
Selenium
Silver
Thallium
Zinc

Miscellaneous
Asbestos
Total cyanides

SOURCE: K. A. Brantner, R. B. Pojasek, and E. L. Stover, "Priority Pollutants Sample Collection and Handling," *Pollution Engineering*, March 1981, p. 35.

process are presently being stored onsite for future treatment. The NYS/DEC plans to develop a pilot project to investigate the potential for plasma arc incineration as a treatment process for the sludge.[14]

Hydrogeological assessments suggest that the leachate collection system is operating successfully.[15] Recent data on water table elevations indicate that ground water in the region between the drain and the landfill is being drawn into the collection system; likewise, data for the area immediately beyond the drain and adjacent to the EDA also indicate flow toward the collection system.[16]

[14]For a description of this technology see *Technologies and Management Strategies for Hazardous Waste Control*, op. cit., pp. 172-173.

[15]These were performed by CH_2M-Hill, contractors for U.S. EPA; their report was not available to OTA. A separate evaluation of the system was made by Woodward-Clyde Consultants, *Evaluation of Proposed Remedial Action Program Love Canal, Project 1, Leachate Collection System, Niagara Falls, New York*, Aug. 10, 1982, prepared for Wald, Harkrader & Ross, Washington, D.C. According to Woodward-Clyde, their conclusions on ground water flow and the efficacy of the leachate collection system were essentially the same as CH_2M-Hill.

[16]Data provided by J. L. Slack, NYS/DEC, May 19, 1983, during a meeting with OTA, NYS/DEC, U.S. EPA, New York State Department of Health (NYS/DOH), and New York State Department of Law (NYS/DOL).

The *containment component* of the remedial action will involve the installation of a barrier wall around the canal, encompassing an area of approximately 49 acres.[17] The wall will be constructed of concrete (a width of 24 inches) and will extend to a depth of about 15 ft to be anchored into clay found at that depth. This clay is very impermeable with hydraulic conductivity (i.e., the rate at which water will move through the strata) estimated to be in the range of 0.1 to 0.01 inches per year.[18] A synthetic membrane cap will be installed to cover the entire 49 acres, including the existing clay cap. This membrane will extend beyond the barrier wall. Thus, it is expected that surface runoff will not penetrate the enclosed area. Twelve inches of sterile earthfill will be placed on top of the membrane cover; 6 inches of top soil will be the final cover. This top soil will be grass seeded. All existing trees, shrubs, and other plants will have been removed from the area prior to installation of the synthetic membrane cap. Only plants with a shallow root system can be allowed to be grown within the 49-acre area. Long rooted plants would eventually penetrate the cap.

The exact placement of the barrier wall will be determined using two sets of data: results obtained from the 1980 Environmental Protection Agency's (EPA) monitoring study and 1983 data on the extent of dioxin contamination in soils immediately surrounding the canal.* EPA has concluded that major contamination from Love Canal compounds does not extend beyond the land immediately adjacent to the canal.**

According to Federal and State officials the wall will serve three purposes:[19]

1. *The wall reduces the volume of water drawn into the leachate collection system.* Based on results from the 1980 EPA monitoring study, officials assume that the water outside the 49-acre perimeter is relatively clean—i.e., contaminants are present at concentrations of only parts per billion or less. By including this clean water in the collection system, the ongoing operation and maintenance costs will be quite large (see table A-2, alternative 1). These costs must be covered by State funds into the indefinite future. Reducing the volume of water that flows through the drainage system should result in a decrease in operation and maintenance costs for the State. Also once the 49 acres are contained by the barrier wall and surface covers, it is expected that very little precipitation will infiltrate into the contaminated area. The rate of flow through the drainage and leachate collection system is expected to decrease below the current average rate of 8 gpm.
2. *The wall provides further control against migration of contaminants from the canal into the residential areas.* Should problems develop with the leachate collection system at some time in the future, the barrier wall will serve as backup protection for EDA residents. Such protection, however, is dependent on there being no undetected damage to the wall or cap over time. While leachate-collection system problems are being resolved, the wall would postpone migration of compounds.
3. *The wall prevents migration of chemicals into the deep aquifer below the landfill.* Results of a recent modeling effort indicate a third advantage to having a barrier wall.[20] After the wall is installed, a reversal of waterflow is expected between the shallow and deep aquifers, i.e., instead of movement from shallow aquifer to deep aquifer, the flow will be from deep aquifer to shallow aquifer. While some reversal may be occurring due to operation of the collection system, the extent of the reversal should be greater with the wall. If the model conclusions are correct, the wall will provide the *only* real means for reducing deep aquifer contamination.

NYS/DEC recognizes the need for continued monitoring once the remedial action has been completed. Although not yet completed, a ground water monitoring strategy is being planned. Because NYS/DEC considers that all mobile compounds will be present in the ground water, no soil or air monitoring is planned. State officials consider that any chemicals bound to the soil will not be mobile. The synthetic cap is expected to prevent volatilization, therefore air monitoring would not be necessary.[21]

The EPA monitoring study identified chemicals in sediment from both storm sewers and storm sewer discharge points in surface waters. Cleanup of the storm sewers within the canal area has been completed and utility pipes were plugged in early 1983. Chain-link fences have been installed to discourage access to

[17]Specifications for the barrier wall at Love Canal are provided in NYS/DEC, *Love Canal Project 1 Site Containment System, Niagara Falls, New York*, vol. 1, August 1982.

[18]L. R. Silka and J. W. Mercer, "Evaluation of Remedial Actions for Groundwater Contamination at Love Canal, New York," *Management of Uncontrolled Hazardous Waste Sites*, Hazardous Waste Control Research Institute, 1982, pp. 159-164.

*The new data on dioxin contamination were not available to OTA. They are being collected by a contractor for NYS/DEC.

**See app. C for OTA's analysis of the EPA conclusions.

[19]R. Dewling, U.S. EPA Region II, personal communication, March 1983; and N. Nosenchuck, NYS/DEC, personal communication, May 1983.

[20]Geotrans, Inc., *Cross-Sectional Simulations To Examine Proposed Wall at Love Canal, New York*, oral presentation given to OTA, May 12, 1983.

[21]Statements made by NYS/DEC during a meeting on May 19, 1981.

contaminated areas in Bergholtz and Blackfoot Creeks. Disposal of the contaminated sewage sediment awaits permits from U.S. EPA. There are 375 drums of this material being stored at the treatment facility. *No action has yet been taken for contaminated storm sewers within the EDA.*

NYS/DEC initiated a monitoring study to determine the extent of contamination within the storm sewer systems located in the EDA. Chemicals of concern in this study include priority pollutants and dioxin. A total of 1,000 samples have been analyzed. The study results are not yet available.

Discussions with the Love Canal Area Revitalization Agency (LCARA) indicate that decisions on the future use of the properties within the EDA have not been made.[22] The Agency plans to delay any such decisions until the OTA review is released. An environmental impact assessment is required by State law before any reuse of the EDA is allowed. LCARA has begun the assessment process.[23] Some sense of urgency is felt by the Agency to resolve the issue of habitability so that revitalization plans can be developed. It should be noted that 100 residences within the EDA are currently occupied. A majority of these (66 units in Griffon-Manor and Senior Citizen housing) are situated adjacent to the canal area.

Uncertainties Associated With the Remedial Action

There are four areas of uncertainty that can affect projections of the long-term integrity of the remedial technology:

1. Remedial action in the EDA.
2. Leak detection systems for the barrier wall and leachate collection system.
3. Long-term monitoring programs.
4. Institutional mechanisms for long-term protection of EDA residents.

While this brief OTA review cannot provide any suggestions for reducing the impact that these uncertainties may have, it is imperative that any decision of habitability consider them and their consequences for continued protection of the residences in the EDA.

Remedial Action in the EDA

Both EPA and NYS/DEC officials have based their analysis of the need (or lack thereof) for remedial action in the EDA, beyond that required for the storm sewer system, solely on the results of the 1980 monitoring study. The major concern was whether contamination observed in this area resulted from migration of chemicals from the Love Canal landfill. Because the EPA monitoring study indicated that the only portions contaminated by Love Canal wastes (within the EDA) were storm sewers and surface water sediments, no large scale remedial action is planned.

According to NY officials, the actual extent of contamination in the storm sewers has not been fully determined.[24] A monitoring study is in progress and once the data are available, a decision will be made about an appropriate method of cleanup. With the installation of the barrier wall and cover, future contamination of the EDA from Love Canal chemicals is not anticipated.

Unfortunately, the 1980 monitoring data were not sufficient to determine if hot spots of contamination exist. Although data are recorded by subsection of the EDA, all values were averaged for the area as a whole. If hot spots do exist and remain untreated, the area will continue to pose a threat to the health of the residents.

Leak Detection Systems

Any analysis of the effectiveness of the remedial action must include some consideration of the capability to detect failure at some time after the system is complete. A major limitation of environmental control systems, however, is that there are few methods to test their continued integrity. Any cracks that develop in the wall could serve as possible routes for migration of chemicals. If the leachate collection system is working properly, such cracks should not pose a threat for outward migration of contaminants. If the system does not operate properly, however, pooling of ground water could occur near subsurface structures. These could consist of rock formations within the area as well as the basement structures containing rubble from destroyed houses on land immediately adjacent to the canal. Subsurface barriers could impede downward movement of ground water and facilitate lateral movement through breaks in the wall.

Officials at NYS/DEC estimate that a well-made concrete wall should last for at least 50 years. Even if it lasts twice the expected lifetime, cracks can be expected. The only means to detect these cracks would be a decrease in the water table elevations. The synthetic membrane cap has an estimated lifetime of 20

[22]R. Morris, Executive Director, LCARA, Niagara Falls, N.Y., personal communication, March 1983.

[23]Statements made by LCARA officials at a meeting on May 19, 1983.

[24]J. Slack, NYS/DEC, personal communication, March 1983, restated at a meeting on May 19, 1983.

years. Evaluation of water-table elevation data and changes in volume of leachate collected in the drainage system are the currently available methods of determining the existence of damage.

Monitoring Programs

A final area of uncertainty concerns long-term monitoring strategies. The monitoring effort that is planned may not provide sufficient warning about migration and accumulation of chemicals outside the barrier wall. The State plan requires only a ground water monitoring program.[25] It is presumed that all mobilized chemicals would eventually migrate into the shallow aquifer system within the barrier wall.

While ground water monitoring is a necessary safeguard for containment technology, it is possible to have contamination of soil and air before substantial levels of contaminants are detected in ground water samples. For example, if cracks develop in the cap, volatile compounds would be released to the air rather than be transported through water. This situation existed when damage to the original cap occurred, and noxious odors were apparent around the canal area.[26] Also, those chemicals that have a strong affinity for organic material can be filtered out of contaminated water as it passes through soils high in organic components; this property is typical of clays found in the vicinity of the canal. Thus, any migration of contaminated water outside of the barrier wall could lead to a build-up of such chemicals in the soil and perhaps be taken up by vegetation. However, at present no plans exist to do any surveillance monitoring of air, soil, or biota.

Such accumulation and uptake of these types of chemicals, often compounds that are very persistent in the environment, would not be detected through ground water monitoring. It is likely that the absence of chemicals in the ground water samples would be interpreted as no contamination of the area surrounding the canal when, in fact, contamination in soil and biota could be present. It may be prudent for NYS/DEC to develop a monitoring strategy that observes biotic changes in areas adjacent to and outside the barrier wall as well as analyzing soil and ground water samples.

Institutional Mechanisms for Long-Term Protection of EDA Residents

The first area of uncertainty surrounding the planned remedial action concerns the need for long-term appropriations by the State of New York and future restrictions on the use of the canal property. Costs for operation, maintenance, and replacement of the wall, covers, and leachate collection system are high. For example, current expenditures for operation and maintenance of the treatment facility is approximately $0.4 million.[27] Included within the lifecycle costs presented in table A-2 are requirements for replacement of the following:

- synthetic cover every 20 years,
- major equipment at the treatment facility every 20 years,
- treatment plant building every 50 years,
- leachate collection system every 50 years.

Institutional and legal mechanisms are needed to provide some assurance of a long-term commitment to meet these costs. Although the current State administration may be completely committed to providing sufficient funds for maintenance of the remedial action, there are no guarantees that 10, 20, or 50 years from now the same commitment will hold. Because the remedial action chosen was environment control rather than waste control, the source of contamination will not be eliminated.

It should be emphasized that the current problem in Love Canal arose because *the original use of the canal was ignored or forgotten and improper use of the land initiated.* The original deed given by Hooker Chemical Co. to the Niagara Falls Board of Education included statements about the hazardous nature of the contents of the canal.[28] The Board chose to ignore these warnings and proceeded with construction of sewer systems that cut through the canal wall and a school that damaged the cap.

Without strong institutional mechanisms that will guarantee continued protection for the EDA, these original problems could reoccur 50 years from now, when the current actors in this unfortunate drama have left the scene. At present the State has a temporary easement for an undetermined time, which provides some protection against improper use of the land. However, the canal property currently has *three different owners:* the southern region is owned by a private citizen; the central section belongs to the Board of Education; the northern portion is owned by the City of Niagara Falls. If at any time in the future the State of New York relinquishes its temporary easement, these owners will be free to utilize their property as they see fit. There are presently no strong legal or institutional mechanisms that will prevent resale and reuse of the land by the current owners.

[25] J. Slack, NYS/DEC, personal communication, March 1983.
[26] Statements made by State officials during a meeting with NYS/DEC, NYS/DOH, NYS/DOL, and LCARA on May 19, 1983.
[27] N. Kolack, NYS/DEC, personal communication, April 1983.
[28] E. Zuesse, "Love Canal, the Truth Seeps Out," *Reason*, February 1981, pp. 16-33.

Appendix B

Design of the EPA Monitoring Study

Summary

One aspect of the OTA review of the 1980 Environmental Protection Agency's (EPA) monitoring study focused on the sampling design. The following specific problems with the sampling procedures used by EPA led OTA to judge the outcome of the study indeterminant with regard to the extent (or distribution) and level of chemical contamination, and its site and regional variability:

- The monitoring study used uneven numbers of sampling sites across media and 12 regions (10 in the emergency declaration area (EDA), the canal, and the control area). The numbers of sampling sites were not in proportion to sizes of the regions, which vary by a factor of 10. One reason for this situation was that EPA assumed that higher levels of contamination existed closer to the canal. Consequently, some regions farther away from the canal had very little sampling; the distribution of sampling among regions in the EDA was particularly inadequate. Initial beliefs about the possible routes of transport of toxic chemicals from the canal to and through the EDA may also have influenced numbers of sampling sites in environmental media. To the extent that these assumptions about patterns remain unproven or unsupported by the results of the study, it can be concluded that the sampling may not have detected contamination present in the EDA which does not correspond to the patterns assumed initially by EPA.
- The numbers of sampling sites used were insufficient to determine accurately the levels of contamination within some regions.
- As for environmental media, the extent of sampling was very broad and included air, surface and ground water, soil, sediment, and biota. However, the effort across media was uneven, and there was no examination of yearly seasonal variations. Within the EDA, those media sampled most extensively were soil, air, and sump water. Ground water was sampled less extensively and biota were sampled least often of any of the environmental media.
- Too few replicate samples were collected per site to evaluate site variability; thus, the data on absolute concentrations of chemicals detected within any one region may not be meaningful.
- The study lacked adequate control data; thus comparisons among regions are difficult. However, as discussed more fully later, DHHS did not rely entirely on the control area data in its habitability decision.

Scope of the EPA Monitoring Study

In 1980, the EPA designed and implemented an extensive monitoring study of the EDA.[1] The goals of the study were:

1. to determine the extent and level of contamination in the area defined by President Carter in his emergency declaration order (fig. B-1),
2. to assess the short- and long-term implications of ground water contamination in the general vicinity of Love Canal, and
3. to assess the relative environmental quality of the EDA.

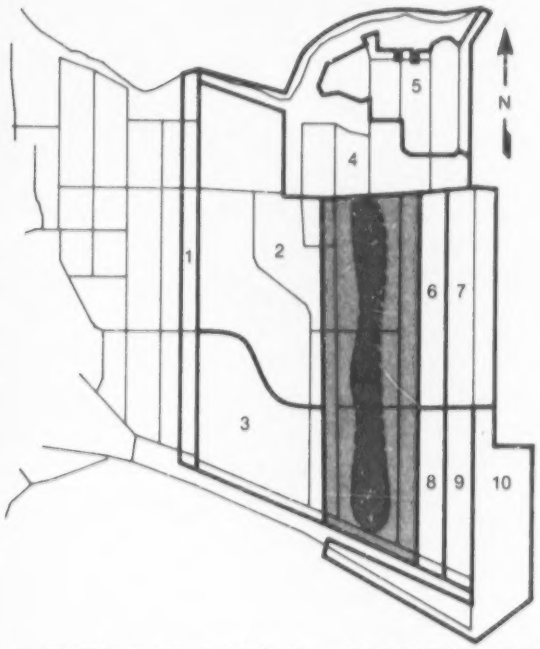
The design of the study was developed based on two assumptions. First EPA expected that the levels of contamination would be very high. Also, EPA assumed that the greatest contamination would exist nearest the canal. EPA sampled five environmental media (air, soil, sediment, water, and biota). Sampling sites were selected in 12 regions: 10 subregions of the EDA, a region directly adjacent to the Love Canal, and a control region that included selected sites throughout the Niagara Falls area. Distribution of sites within a region was generally random. The number of sampling sites per region decreased with increased distance from the canal. Additional sites were sampled at the request of EDA residents and at places of possible migration routes from the canal landfill. A total of 150 chemicals were chosen for analysis, including chemicals that were known to have been deposited within the landfill.

The EPA evaluated the data in two ways: one compared absolute concentrations of chemicals detected within the EDA with available environmental standards and with concentrations detected at control sites.[2] Of secondary importance to EPA was a comparison of the frequency of detection of chemicals in the EDA to the frequency detected at control sites. EPA concluded that the only places within the EDA with significant contamination from Love Canal chemicals were the sediments of storm sewer systems and their surface water outfalls.

[1] *Environmental Monitoring at Love Canal* (Washington, D.C.: U.S. Environmental Protection Agency, EPA-600/4-82-030, May 1982), vol. I, II, III.

[2] R. Dewling, U.S. EPA Region II, personal communication during a meeting with OTA on May 12, 1983.

Figure B-1.—The 10 Subregions of the EDA Included in the EDA Monitoring Study



---Indicates approximate location of the canal landfill within the Love Canal region.

SOURCE: Woodward-Clyde Consultants, *Evaluation of Proposed Remedial Action Program Love Canal, Project 1, Leachate Containment System, Niagara Falls, New York*, prepared for Wald, Harkrader & Ross, Washington, D.C., August 1982.

Evaluation of the Sampling Effort

There are certain principles for environmental sampling that must guide any monitoring program.[3] OTA used these principles as criteria for an evaluation of the EPA monitoring effort. As indicated in table B-1, the OTA analysis suggests that the number of sites and replicate samples taken at each site were insufficient to determine extent and level of contamination for all of the EDA.

1. Are spatial and temporal factors considered?

The EPA study attempted to investigate spatial patterns that could be evidence of chemical migration from the landfill. Sites were chosen to represent three regions: an area adjacent to the canal, the EDA, and control area. No samples were taken directly from the landfill site for fear of interfering with the integrity of the cap and sidewalls of the canal. Because of the time constraints imposed on EPA, there was no attempt to determine annual variability in the extent of contamination.

2. Were the choice and number of control sites appropriate to distinguish among levels of contamination for the control area, EDA, and Canal regions?

There is a general consensus within the scientific community that all environmental studies require baseline data to which the test area can be compared. Such baseline data can be control sites that are similar to the test sites except for the variable of concern (in this study the presence and concentrations of Love Canal chemicals); baseline data can also be established standards for the chemicals of concern. If statistical analyses are to be conducted comparing control and test site, uncertainties in interpretation can be reduced if numbers of control sites are equal to, or closely approximate, numbers of test sites.

Because of the way EPA designed the sampling effort and because of the fact that the controls were located farthest from the canal, the number of control sites was very small. For example, 11 control sites were chosen for ground water samples. The number of control sites for other environmental media also was small; a maximum number of nine sites was sampled as controls for soil analyses. For surface water and sediment, as well as drinking water, only five control sites were identified. Sump water and storm sewers (both water and sediment) were sampled only at one site in the control area.

Because the control sites for ground water were adjacent to and formed a ring around the EDA, there is concern that some of these sites were not suitable as controls. For example, it is not clear that these control sites were free of contamination from chemicals similar to those disposed in the canal landfill. Because the landfill had been in operation since the late 1940's, there is the possibility that chemicals could have migrated within the ground water to sites designated as controls. For example, analysis of water table elevations prior to installation of the leachate collection system indicate that flow of the overburden ground water system was away from the canal, toward the location of control sites.[4] There is the added problem that at least two of the control sites were located ad-

[3]R. H. Green, *Sampling Design and Statistical Methods for Environmental Biologists* (New York: John Wiley & Sons, 1979).

[4]Woodward-Clyde Consultants, *Evaluation of Proposed Remedial Action Program Love Canal, Project 1, Leachate Containment System, Niagara Falls, New York*, prepared for Wald, Harkrader & Ross, Washington, D.C., August 1982.

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Table B-1.—Criteria Used To Evaluate EPA Sampling Effort

Criteria	Design of the study
Spatial/temporal factors:	• Only spacial factors included in the study • No seasonal variations considered
Choice/number of controls:	• Controls for ground water adjacent to EDA; possibility of chemical migration to control sites from Canal • Two control sites adjacent to another landfill • Number of control samples too few for adequate analysis
Equal number of sites:	• Unequal sample sites among regions • Not allocated in proportion to size of the regions
Replicates:	• Inconsistency in number of replicates taken per site • Not used to estimate variability within and among sites • Replicates treated as separate site samples
Verification of methods:	• No verification of sampling, handling, and analytical methods done prior to initiation of the study

EDA = emergency declaration area.

SOURCE: Office of Technology Assessment.

jacent to another known landfill, southwest of the Love Canal area.

3. Were equal numbers of sites allocated among regions and environmental media?

Equal (or nearly equal) numbers of sampling sites among regions facilitate interpretation and reduce uncertainties in results of statistical comparisons among regions. If very different numbers of sites are used, indeterminance can exist for those sites sampled least often. If equal numbers of sampling sites per region are not possible, a standard practice is that the numbers of samples be allocated in proportion to the size of each region.

Because of the assumptions guiding the design of the EPA study, the number of sites sampled across regions were not equal nor were they in proportion to the differences in sizes among regions, as indicated in table B-2. For example, the entire EDA is approximately 3½ times the size of the Love Canal region (see table B-3), yet the number of sampling sites do not reflect this difference. It should be noted that the sampling effort did include sites chosen at the request of EDA residents and because of possible migration routes from the landfill.

Even for subregions within the EDA, the number of sites were not allocated on a proportional basis (see figs. B-2 through B-9.) For some media, site locations are naturally limited. For example, sump samples were obtained only in houses located in wet areas (fig. B-5); surface water and sediment samples were possible only from creeks (fig. B-7). However, for environmental media such as air, soil, and ground water (both shallow and deep) allocation could have been proportional to the area of each subregion. If this had been done, the data would reflect a more accurate picture of environmental contamination over all of the EDA.

It should be emphasized that by designing a sampling effort with preconceived assumptions about the outcome of the study, the use of the data can be limited. In this instance, the EPA data were used to make judgments about the overall habitability of the EDA. Because numbers of sites sampled decreased with increasing distance from the canal, uncertainties exist about contamination in some areas. For example, EDA-1 had samples collected from only one or two sites (depending on the medium of concern) for the entire region. This sampling effort is hardly sufficient to determine the overall level of contamination for this subregion.

4. Were replicate samples taken for each site?

It is very important that any monitoring effort include replicate samples (i.e., identical samples from one site). The appropriate number of replicates will vary depending on the anticipated impact that variability within individual sites may have on the conclusions drawn from the data. If an assessment relies on absolute concentrations, replicate samples can be used to estimate the variance in concentration at a particular site. Without replicates, confidence in the absolute concentrations cannot be indeterminate.

Replicate samples from one site are used to estimate the amount of variance inherent at that site. Samples collected at several different sites enable an estimation of the variability inherent in a region. These estimates of variability may not be equal. Differences between them will depend on the evenness of distribution of a chemical within the environment, the properties of the medium being examined, and the presence of those factors that enhance or inhibit degradation of the chemical.

Table B-2.—Number of Sites and Samples for Target Substances

Environmental media	Regions[a]												
	1	2	3	4	5	6	7	8	9	10	EDA	LC	C
Ground water:													
Shallow well:													
Sites	1	13	9	5	3	3	6	3	2	4	49	18	11
Samples[b]	1	11-13	8-9	5	2-3	2-3	5-6	2-3	1-2	1-4	36-47	9-21	9-11
Deep well:													
Sites	1	11	9	5	5	2	6	3	2	6	50	17	15
Samples	0	7-10	4-5	2-4	2-4	1	4	1	1	2-4	24-32	6-13	11-16
Sump water:													
Sites	2	2	0	8	1	3	7	2	4	4	33	13	1
Samples	1-2	8-18	0	9-22	3-8	2-8	8-22	1-6	3-14	7-9	92-104	6-16	1-5
Drinking water:													
Sites	1	3	1	7	3	4	4	3	3	2	34	3	5
Samples	1	1-3	1	3-7	1-3	2-4	1-4	2-3	2-3	2	10-31	1†,3	1†,4-5
Surface water:													
Sites	0	0	0	5	0	0	0	0	0	0	5	0	5
Samples	0	0	0	1†,2-4	0	0	0	0	0	0	2-4	0	1†,3-5
Storm sewer water:													
Sites	1	3	3	6	1	1	1	1	1	4	22	4	1
Samples	1	3†	1,3†	1-4	1	1†	1†	1	1†	1,4†	5-19	2,3†	1
Soil:													
Sites	7	15	9	16	12	9	16	9	10	10	113	23	9
Samples	2-5	14-15	4-9	9-16	9-12	1-9	8-15	6-9	3-10	8-10	71-109	13-23	5-9
Volatiles	9	28	18	30	24	18	31	18	19	18	213	45	17
Sediment:													
Storm sewer:													
Sites	1	3	3	6	0	1	1	1	1	4	22	4	1
Samples	1	1-3	1-2,3†	1-3	0	1	1	1	1	1-2	5-15	1-4	1
Surface water:													
Sites	0	0	0	5	0	0	0	0	0	0	5	0	5
Samples	0	0	0	1†,4	0	0	0	0	0	0	3-4	0	1-5
Air:													
Living:													
Sites	1	6	5	8	5	6	6	6	6	5	54	6	4
Samples T[c]	9	60	52	76-79	60-61	66	56	49-50	62	46-47	538-542	63-64	30-31
Samples P	3	26	20	48	25-26	27	42	35	43	22	292	32	28
Basement:													
Sites	0	6	0	7	5	6	6	6	6	0	42	6	0
Samples T	0	10-11	0	12	12	10	22	9	10	0	83-84	11	0
Samples P	0	12	0	11	11	9	20-21	9	11	0	85-86	8	0
Outdoor:													
Sites	0	6	0	7	5	6	6	6	6	0	42	6	0
Samples T	0	11	0	10	12	9	21	11	11	0	81-83	10	0
Samples P	0	9	0	9	12	7-8	19	10	9-10	0	77-79	10	0

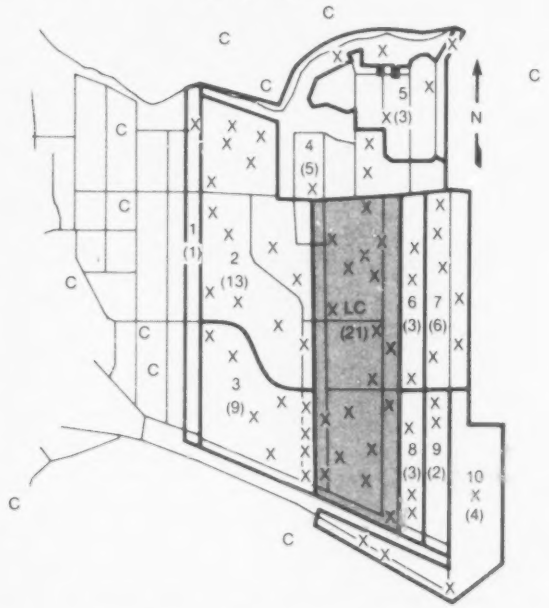
†Sampled only for K-stable potassium, cesium, radium, americium.
[a] Columns 1 through 10 represent subregions in the emergency declaration area (EDA); LC represents the region adjacent to the Canal, and C represents the control region.
[b] Represents range of total analytical samples verified and entered into the EPA data base for each target substance; e.g., in EDA-2 some target substances were analyzed using 11 shallow well samples and other substances using 13 samples.
[c] T represents the total number of samples analyzed with the Tenax method; P represents the total number analyzed with the PFOAM method.

SOURCE: U.S. Environmental Protection Agency, *Environmental Monitoring at Love Canal, Volume III.*

As illustrated in table B-2, multiple samples per site were collected only for sump water samples, for volatile compound analyses in soil, and for air analyses.[5] For example in EDA-2, two sump water sites were identified from which 8 to 18 samples were collected for chemical analyses. The range (8 to 18) indicates that for some compounds as few as 8 samples were analyzed and recorded in the data base; for other chemicals, analyses were performed with 18 samples collected at the two sites. For all soil sites, two samples per site were collected for analysis of volatile compounds. Two methods were used to analyze air samples. For the Tenax method nearly 10 replicates per site were collected; four replicates per site were collected for analysis using the PFOAM method. It is dif-

[5] *Environmental Monitoring at Love Canal,* op. cit., vol. II.

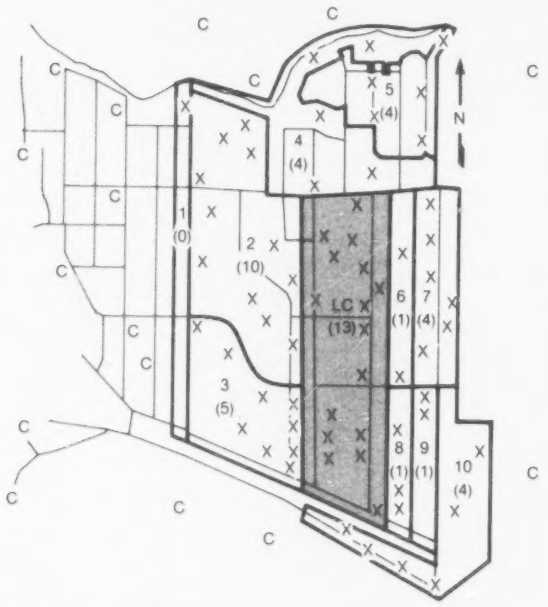
Figure B-2.—Distribution of Shallow Well Sampling Sites



KEY: Numbers denote subregions; X indicates approximate location of each well; C represents location of control wells; ( ) indicates maximum number of samples collected per region.

SOURCE: *Environmental Monitoring at Love Canal* (Washington, D.C.: U.S. Environmental Protection Agency, EPA-600/4-82-030, May 1982), vol. III, p. 14.

Figure B-3.—Distribution of Deep Well Sampling Sites



KEY: Numbers denote subregions; X indicates approximate location of each well; C represents location of control wells; ( ) indicates maximum number of samples collected per region.

SOURCE: *Environmental Monitoring at Love Canal* (Washington, D.C.: U.S. Environmental Protection Agency, EPA-600/4-82-030, May 1982), vol. III, p. 19.

Table B-3.—Approximate Size of EDA Study Regions

Region	Square yards (in thousands)	Football field[a] equivalence
1	80	16
2	300	60
3	100	20
4	200	40
5	90	18
6	50	10
7	100	20
8	30	6
9	30	6
10	70	14
Total	1,000	200
Love Canal region	300	60

[a]Calculated by assuming a football field is approximately equal to 5,000 yd².

SOURCE: Calculated from maps provided by the Love Canal Area Revitalization Agency.

ficult to determine whether these multiple samples were actual replicates.

If, in fact, these multiple samples were collected as replicates, EPA did not follow the normal practice of using them to estimate variability within the site. Such estimates are particularly important when low levels of contamination are encountered and when an assessment of habitability is based on absolute concentrations of chemicals, as was the case in this study. The decision to treat replicates as actual samples was unfortunate as it increases uncertainties about the significance of differences in observed concentrations among control, EDA, and Love Canal regions.

5. Were the sampling and analytical techniques verified?

All sampling and analytical methods have certain biases associated with them—e.g., differences in results can occur if slightly different procedures are followed, if different personnel perform the analyses, and if different collection and analytical equipment are used. If results of environmental studies are to be properly interpreted, it is necessary to identify these biases.

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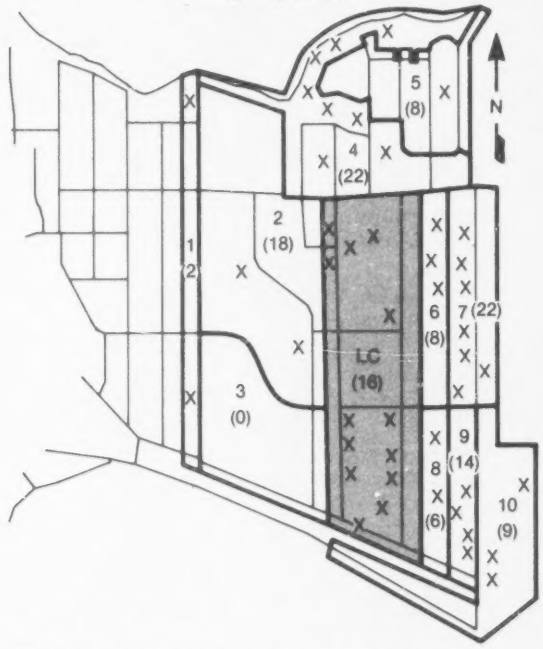
Figure B-4.—Distribution of Soil Sampling Sites

KEY: Numbers denote subregions; X indicates approximate location of each site; ( ) indicates maximum number of samples (nonvolatile) collected per region.

SOURCE: *Environmental Monitoring at Love Canal* (Washington, D.C.: U.S. Environmental Protection Agency, EPA-600/4-82-030, May 1982), vol. III, p. 23.

Figure B-5.—Distribution of Sump Water Sampling Sites



KEY: Numbers denote subregions; X indicates approximate location of sites; ( ) indicates maximum number of samples collected per region.

SOURCE: *Environmental Monitoring at Love Canal* (Washington, D.C.: U.S. Environmental Protection Agency, EPA-600/4-82-030, May 1982), vol. III, p. 33.

Because of time constraints, EPA could not conduct any preliminary analyses that would have identified biases inherent in the techniques chosen for this monitoring study.

In addition, EPA did not verify that the methods used for sample collection and analysis were suitable for the conditions at Love Canal. For example, the methods of obtaining samples could have been a major contributor of the large number of below detection results that were obtained. Soil samples were obtained by using a soil corer, which obtained a core 1¾ inches in diameter and 6 feet in depth. Seven cores were taken at a site; two cores, representing two samples per site, were analyzed for volatile chemicals. The remaining five cores were homogenized and treated as *one sample* per site. Such a method could have serious consequences for detecting soil contamination. If the compounds are present at low concentrations and/or within only a small region of the core, the practice of compositing *five* cores to produce one sample will dilute any concentration level and make detection extremely difficult. Because of this dilution factor associated with this particular sampling technique, even if hot spots exist at a site the measured values would be lower than actual environmental concentrations. *The use of such sampling techniques calls into question the validity of using absolute contamination values as the basis for a habitability decision.*

Similar problems existed for ground water samples. For example certain ground water samples were invalidated by EPA, because it was suspected that inadequate purging had occurred.[6] Hydrant water was used as a drilling fluid during construction of the wells. Prior to collecting samples the wells had to be purged, removing all hydrant water. EPA officials thought that hydrant water had been collected rather than aquifer water. Appropriate location of sampling wells is critical to obtaining representative samples with which to judge the extent of ground water contamination. Plumes of chemicals, which may have densities greater than water, can travel in directions different from the

[6] *Environmental Monitoring at Love Canal*, op. cit., vol. I, p. 238.

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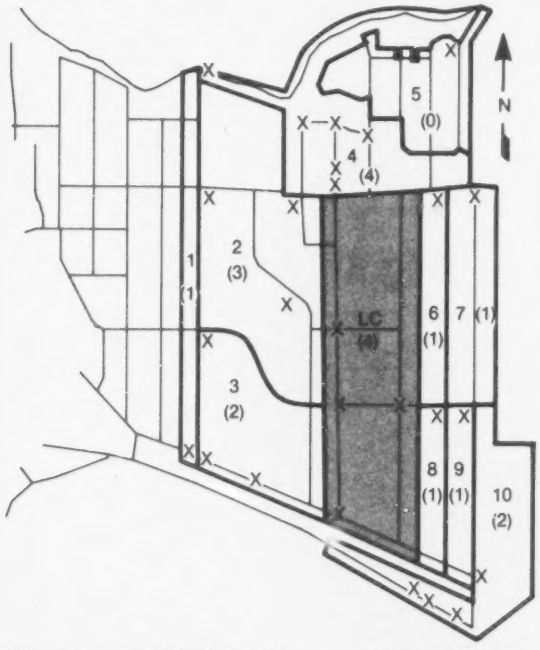
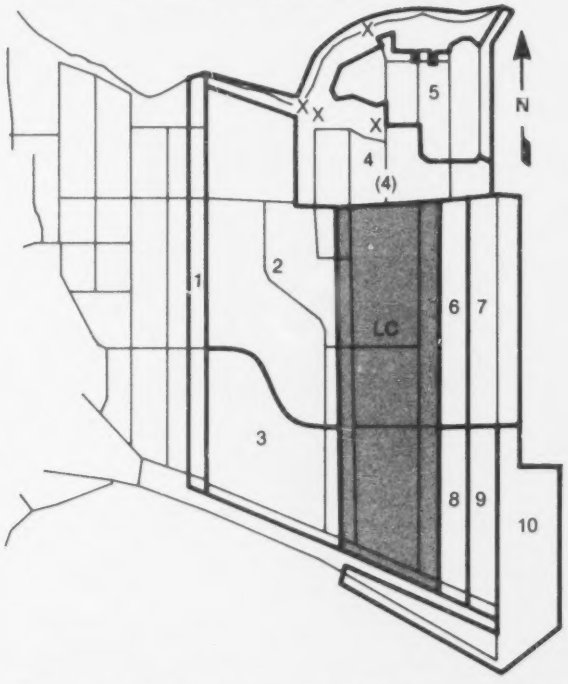
Figure B-6.—Distribution of Storm Sewer Sampling Sites



KEY: Numbers denote subregions; X indicates approximate location of each storm sewer; ( ) indicates maximum number of samples (water or sediment) collected per region.

SOURCE: *Environmental Monitoring at Love Canal* (Washington, D.C.: U.S. Environmental Protection Agency, EPA-600/4-82-030, May 1982), vol. III, p. 41.

Figure B-7.—Surface Water Sampling Sites Along the Black Creek and the Bergholtz Creek



KEY: Numbers denote subregions; ( ) indicates maximum number of samples collected for region 4.

SOURCE: *Environmental Monitoring at Love Canal* (Washington, D.C.: U.S. Environmental Protection Agency, EPA-600/4-82-030, May 1982), vol. III, p. 51.

ground water flow and can migrate into undetected fissures.[7] Thus, when this occurs analysis of samples taken from those wells placed to match ground water flow patterns would not likely lead to detection of the contaminated plume.[8]

Analytical methods likewise were not verified for Love Canal environmental conditions and study mechanisms prior to initiation of the monitoring effort. If EPA had attempted such verifications, problems associated with sample extraction (e.g., for dioxin), analyses of air samples using the PFOAM method, and uneven analytical capabilities among laboratories could have been resolved before enormous effort and resources had been expended. Absence of the verification was probably a direct result of the fact that EPA was under great pressure to do the study quickly. In retrospect, providing time prior to initiation of the monitoring study to verify methods likely would have resulted in more definitive answers.

Proper sample handling is a critical element in environmental monitoring programs. All samples taken in the field tend to lose a variable portion of the substances to be monitored during sampling, handling, and storage. A standard technique for determining the percent of loss is to add a specified amount of known substance (to "spike") to certain field samples. The concentration of the spiked substance is measured in the laboratory; any differences between the amount added in the field and the amount measured in the laboratory represents the percent lost during sample handling. Analytical results of unspiked samples thus can be adjusted to reflect these losses. Loss of concentrations during sample handling can result from chemicals bonding to the sample medium or containers, to vola-

[7]The geology beneath the canal landfill has not been studied extensively. Fractures have been noted in parts of the Niagara Falls region. E. Koszalka, U.S. Geological Survey, Long Island, N.Y., personal communication, March 1983.

[8]Ground water monitoring problems are discussed further in *Technologies and Management Strategies for Hazardous Waste Control*, "Chapter 7: The Current Federal-State Hazardous Waste Program" (Washington, D.C.: U.S. Congress, Office of Technology Assessment, OTA-M-196, March 1983).

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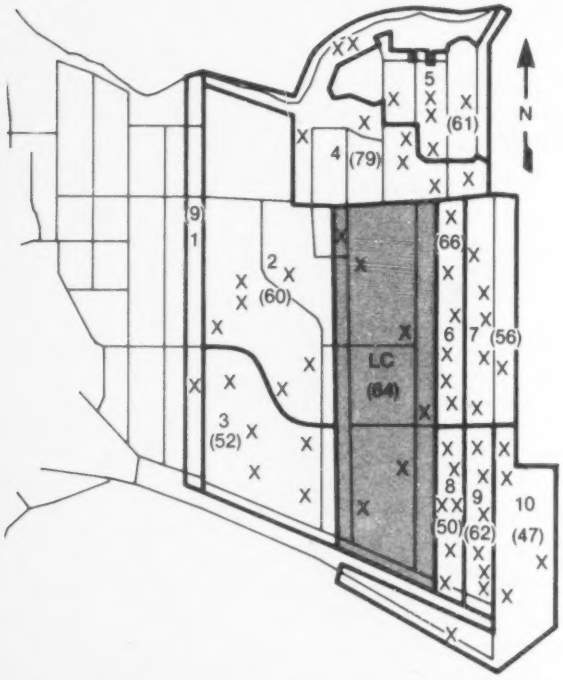
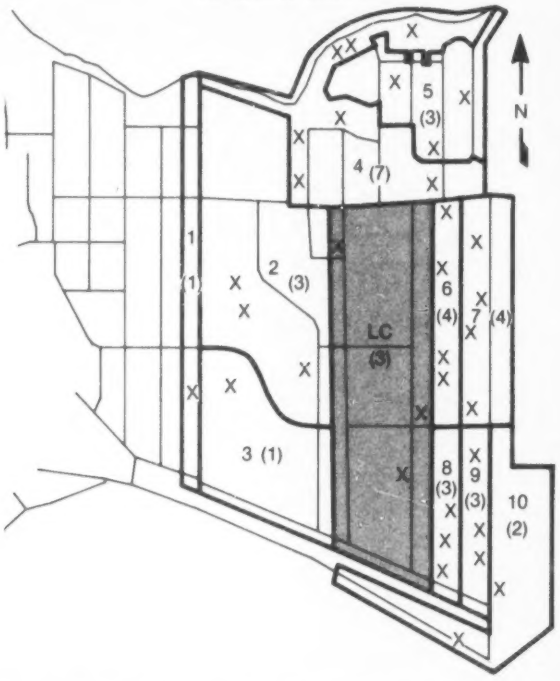
Figure B-8.—Distribution of Air Sampling Sites



KEY: Numbers denote subregions; X indicates approximate location of each site; ( ) indicates maximum number of samples collected per region.

SOURCE: *Environmental Monitoring at Love Canal* (Washington, D.C.: U.S. Environmental Protection Agency, EPA-600/4-82-030, May 1982), vol. III, p. 61.

Figure B-9.—Distribution of Drinking Water Sampling Sites



KEY: Numbers denote subregions; X indicates approximate location of each site; ( ) indicates maximum number of samples collected per region.

SOURCE: *Environmental Monitoring at Love Canal* (Washington, D.C.: U.S. Environmental Protection Agency, EPA-600/4-82-030, May 1982), vol. III, p. 74.

tilization, or to other chemical-physical processes that may occur during handling and storage.

This technique was not employed in the EPA study for water, soil, or sediment samples. Blind spiked samples were included in the field sample analyses for air. Consequently, reliable estimates of loss for most substances cannot be made. (However, EPA did estimate percent recovery for extraction of dioxin from field samples.) Particularly for volatile chemicals and for those samples collected during the warmest periods of the monitoring program (which spanned August to October), loss of substances could have occurred. Analysis of air samples, however, did not reveal pronounced seasonal variations. It is uncertain whether other media would reveal a similar lack of variation.

Field spiking was omitted from the EPA protocols to eliminate the possibility of accidental contamination of all field samples with target substances.[9] In addition EPA was presented with certain difficulties regarding implementation of spiking for their field samples. Spiking with all 150 target substances would be extremely difficult; choosing a few compounds to serve as representatives of the total set has several uncertainties associated with it. For example, it would be difficult to verify that the representative compounds behaved similarly to the 150 chemicals within the variety of environmental media investigated in this study. Identification of these representative compounds would have required additional time, and EPA was under pressure to complete its large study within 6 months.

Conclusions About the Sampling Strategy

Perhaps the most serious failings of this study were:

[9]J. Deegan, statement and supplementary testimony before the subcommittee on Commerce, Transportation, and Tourism of the Committee on Energy and Commerce, U.S. House of Representatives, 97th Cong., serial No. 97-197, Aug. 9, 1982.

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1. the inadequate numbers of sites sampled in different regions,
2. varying intensity of sampling of different environmental media, and
3. the lack of replicate samples with which to estimate site variability in concentrations of chemicals.

The numbers of collected samples per region and the number of measurements available per target substance are insufficient to serve as a representative picture of the potential contamination either in the EDA or within subregions of the EDA. For example, EDA-1 covers an area of approximately 80,000 square yards (approximately equal to 16 football fields, as shown in table B-3). Only one or two sites, depending on the environmental media, were sampled to represent potential contamination. Similarly, nine or fewer sites were sampled for all media to represent EDA-6, an area approximately equal to 50,000 square yards and directly adjacent to the Love Canal region.

The lack of sufficient sites and inability to estimate sample variations within sites presents serious consequences for an assessment of habitability based on absolute concentrations. Without estimates of variability, confidence in reported concentration values must be limited. For example, "trace" is considered to represent levels less than 100 parts per billion (ppb) in the EPA study; the possibility exists that site variability could range by an order of magnitude. Analysis of replicate samples from a site would verify whether trace represents 100 ±10 ppb or 100 ±200 ppb. Because human health effects can result from chronic exposure to concentrations in the ppb and parts per million (ppm) ranges, it is necessary to know with some level of confidence that the values reported for an area represent actual environmental concentrations.

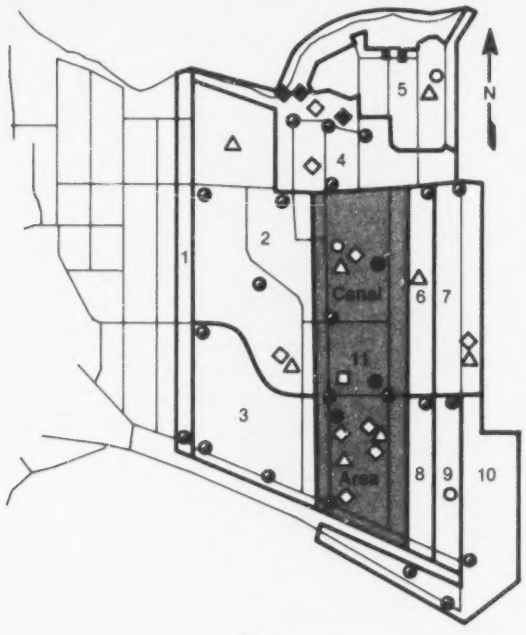
Dioxin is probably the most toxic of the contaminants (in low concentrations) known to be present in Love Canal, and an analysis of the data for this chemical illustrates the OTA concern about the sampling effort. Monitoring for dioxin was insufficient with respect to extent, level and replication, as shown in table B-4 and figure B-10. Only 6 out of 21 submedia were sampled in the EDA; 3 were sampled in control areas; and 7 submedia were analyzed in the Love Canal. Of the 10 regions in the EDA, only 2 were sampled for sump water contamination and 3 each for air and soil. No samples were collected in deep well, shallow well,

Table B-4.—Sampling Effort for Dioxin

	EDA (10 subregions)		Controls		Love Canal region		
	Total regions	Total sites	Total samples	Total sites	Total samples	Total sites	Total samples
Water:							
Deep well	0	0	0	0	0	3	2
Shallow well	0	0	0	0	0	3	2
Sump	2	4	0	0	0	5	2
Surface	1	3	3	1	1	0	0
Drinking	0	0	0	0	0	0	0
Storm sewer	0	0	0	1	1	4	1
Sanitary sewer	0	0	0	0	0	0	0
Soil	3	3	4	0	0	3	4
Sediment:							
Sump	0	0	0	0	0	0	0
Storm sewer	9	18	18	0	0	4	4
Sanitary sewer	0	0	0	0	0	0	0
Surface water	1	3	3	0	0	0	0
Air:							
Living area	3	2	3	1	1	1	1
Basement	0	0	0	0	0	0	0
Outdoor	0	0	0	0	0	0	0
Biota:							
Oatmeal	0	0	0	0	0	0	0
Potatoes	0	0	0	0	0	0	0
Crayfish	0	0	0	0	0	0	0
Dog	0	0	0	0	0	0	0
Maple	0	0	0	0	0	0	0
Mice	0	0	0	0	0	0	0
Worms	0	0	0	0	0	0	0
Totals		33	36	3	3	23	16

SOURCE: U.S. Environmental Protection Agency, op. cit., Vol. II.

Figure B-10.—Distribution of Dioxin Sampling Sites



SOURCE: *Environmental Monitoring at Love Canal* (Washington, D.C.: U.S. Environmental Protection Agency, EPA-600/4-82-030, May 1982), vol. III, p. 77.

drinking water, storm sewer water, or sanitary sewer water. Surface water and sediment were sampled in one subregion. It should be noted, however, that the solubility of dioxin in water is extremely low (0.2 ppb). Storm sewer sediment was collected in nine of the EDA regions. Also, this substance has not been detected previously in air samples, except when present on dust, near incinerators, or in smoke from forest fires. Thus, EPA may have reduced the extent of sampling because of assumed distribution primarily in soil and sediment.

For a determination of the possible level of dioxin contamination in the EDA, the amount of sampling was very limited for dioxin. For most of the regions, including the 10 subregions of the EDA, no more than five sites were sampled per region. Storm sewer sediment sampled in the EDA is the one exception. Given the large area covered by both the Love Canal and EDA (see table B-3), this level of sampling effort seems insufficient to estimate the potential contamination in the Love Canal area.

Within each of the major sampling regions (EDA, control area, and Love Canal), few replicate samples were taken. Variability in concentrations within a single site could be possible, but without replicates this variability cannot be estimated. Lack of replicates reduces the certainty associated with comparison of dioxin concentrations among the EDA, Love Canal, and control area. Distinctions *between* regions require estimates of variation *within* each individual region as a basis for comparison. Consequently, in the extreme case of no replication, it is impossible to determine whether the regions, regardless of absolute concentrations, differ because of normal site variability or because of actual regional variations.

OTA compared this extent and level of sampling for dioxin at Love Canal with recent EPA protocols for dioxin sampling in Missouri.[10] The Eastern Missouri Dioxin program has collected samples from some 30 areas, including Denny Farm (1979), Times Beach (1982), and Quail Run (1983). Two important differences emerged.

1. In Eastern Missouri, preliminary surveys were conducted to identify areas of highest contamination.
2. Within the boundaries of these highly contaminated areas, the level of sampling was between 4 and 37 times as great as in the Love Canal EDA (table B-5).

Table B-5.—Comparison of Dioxin Sampling Effort Between Eastern Missouri and the EDA

	Area (acres)	Total samples	Samples per acre
Denny Farm (1979)	4.5	30	6.7
Love Canal EDA (1980)	200	36	0.18
Times Beach (1982)	640	500-600	0.78-0.93
Quail Run (1983)	24	113	4.7

SOURCE: Environmental Protection Agency, Region VII, Kansas City, Mo., May 1983.

Some important differences exist between the Eastern Missouri program and the Love Canal effort. First, the analytical capability to analyze for dioxin has advanced tremendously since 1980. Second, the detection limits are different for the two programs: 20 parts per trillion for Love Canal and 1 ppb for Eastern Missouri. This leads to significant gains in turnover time and laboratory capacities. Third, at Love Canal, EPA was faced with analyzing for a broad diversity of substances known to have been disposed in the landfill, while in the Eastern Missouri program, dioxin was the *only* target substance. Fourth, in Eastern Missouri, EPA is not operating under a presidentially declared Federal Emergy Management Agency state of emergency as was the situation at Love Canal. Therefore, time was not a limiting factor.

[10]Gale Wright, William Keffer, Will Bun, William Fairless, and John Whitland, U.S. EPA Region VII, Kansas City, Mo., personal communication, May 27, 1982.

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Appendix C

Results of the EPA Study Related to the Habitability Decisions

Summary

Until there is agreement about the possible level of chemicals in samples that contained no detectable concentrations, it is pointless to dwell on the quantitative aspects of health risk posed by chemicals from Love Canal. If the concentrations are in the parts-per-billion (ppb) range, the risk has to be judged to be very low and probably acceptable. If the concentrations for some chemicals are 1,000 times higher, in the parts-per-million (ppm) range, the risks are probably not acceptable. According to the Environmental Protection Agency (EPA), the concentrations are in the ppb range; according to the National Bureau of Standards (NBS), they could near 1 ppm.

OTA does not agree that the ppm estimate is realistic for all chemicals, and it tends to accept EPA's estimates, but OTA does agree with NBS that further documentation from EPA is necessary to settle the matter. A resolution between EPA and NBS might be reached by an examination of a subset of EPA's records. Also, if additional monitoring is carried out before or during rehabitation of the emergency declaration area (EDA), EPA should consult with NBS to ensure that quality control measures are adequate.

Basis of the Habitability Decision

The major input to the habitability decision was data generated by the EPA monitoring study.[1] The Department of Health and Human Services (DHHS) used absolute concentrations of chemicals found in EDA and assessed the relationship of these concentrations to potential health problems. DHHS also reviewed data about health problems observed in EDA and Love Canal residents and used professional judgments about possible human health effects resulting from exposure to chemicals deposited in the canal landfill.

The OTA review concentrated on the EPA monitoring data and possible health effects associated with Love Canal chemicals. OTA inspected but did not evaluate the validity of reported health problems of residents nor question the professional judgments of the DHHS officials. The results of the OTA analysis indicate three areas where uncertainties in the data could have a major impact on the DHHS decision. These areas include:

1. the range of variability associated with values reported for chemicals detected, nondetected, and trace;
2. uncertainties in potential health effects associated with Love Canal chemicals; and
3. problems associated with comparing data for the EDA with data in control areas.

Problems With Statistical Comparisons of EPA Results

A major statistical problem is related to the small numbers of controls used in the EPA analysis.[2] The power to detect differences in contamination between the EDA and control areas and between Love Canal and control areas has been questioned.[3] These criticisms that the canal cannot be distinguished from the control are accepted as valid by EPA. This creates uncertainty for a conclusion that the EDA is as habitable as the control areas to which it was compared. Silbergeld has attacked the EPA monitoring study on insufficiency of statistical power:

> The small number of control area sampling sites seriously reduced the ability to detect differences in chemical contamination between the Declaration Area and the control area.

The absence of power to distinguish between the canal and the control areas seriously compromises any conclusions to be drawn from comparing Love Canal to the EDA and EDA to the control areas because, in most cases, statistically there are no differences between Love Canal and the control areas. The absence

[1] D. Rall, National Institute of Environmental Health Science, Research Triangle Park, N.C., and B. Paigen, Children's Hospital, Oakland, Calif., personal communications, May 1983. See *Environmental Monitoring at Love Canal: Interagency Review*, comments by DHHS, NBS, and EPA (Washington, D.C.: U.S. Environmental Protection Agency, Office of Research and Development, May 1982).

[2] E. Silbergeld, Environmental Defense Fund (EDF), testimony before the Subcommittee on Commerce, Transportation, and Tourism, Committee on Energy and Commerce, U.S. House of Representatives, 97th Cong., serial No. 97-197, August 1982, pp. 68-103.

[3] R. J. Cook, testimony before the Joint Public Hearing on Future Uses of the Love Canal Hazardous Waste Site and Adjacent Property, State of New York, Assembly Standing Committee on Environmental Conservation, Assembly Subcommittee on Toxic and Hazardous Substances, Feb. 17, 1983.

of statistical power to distinguish between the Love Canal and control areas results from the small number of control area samples, and nothing can be done at this time to make up for that deficiency. It is important to remember that differences almost certainly exist in chemicals actually present in the Love Canal and control areas. But the differences cannot be shown because of too few control area samples.

Independent analysis of the EPA data shows that the greatest number of samples analyzed from any one medium in the control area was 33, compared to 539 in the EDA.[4] For every chemical tested there were fewer than 10 samples in a majority of the media. Table C-1 describes the number of samples needed to have a good chance of detecting differences between two areas. Formally, this table gives required sample size for a one-sided, alpha 0.10, Z-test on two proportions to achieve a power of 0.90. In less formal language, if the real frequency of positive detections of chemicals in the control sample is equal to 5 percent (0.05) and the positive detection rate in the EDA is equal to 20 percent, a minimum of 61 samples from each region must be analyzed to have a 90-percent chance of detecting this (fourfold) difference. Because the maximum number of samples analyzed in the control region was 33 from any one medium and most of the time it was only 10 samples, even a fourfold difference in chemical detection rates would not be recognized. Because differences in detection rates between the EPA and control area are much smaller than these values, statistical significance between the EDA and controls could not be expected.

OTA concludes that any decision based on differences in detection frequencies between the Love Canal, EDA, and control area must be discounted because of the weak statistical basis of the EPA study. EPA apparently agrees with this assessment and asserted that making such comparisons is not the normal way to judge whether an area is contaminated.[5] Rather, EPA would rely on measured absences of chemicals to show the area is not contaminated. Some type of baseline data, however, are needed to make such judgments. These baseline measurements could be either control area analyses or established environmental standards. Unfortunately, few of the chemicals disposed in the canal landfill have established environmental standards.

Range of Variability for Reported Values

Except for some compounds detected in sumps and storm sewer systems, concentrations of chemicals reported for the Love Canal region were generally quite low, as illustrated in tables C-2 and C-3. The maximum values reported for organic chemicals detected in the EDA, Love Canal, and control regions range from 0.05 to 263 ppm. In the Love Canal, very high concentrations were reported for sump sediment (16,500 ppm); however, these samples were taken from sumps of homes that had been built directly adjacent to the canal landfill. Table C-3 provides reported maximum values for those media where dioxin was detected. These values were 672 ppb found in storm sewer sediment within the EDA and 37 ppb detected in surface water sediment, also in the EDA. For all other environmental media, results of dioxin analyses were below EPA's reported detection limits (20 ppt). In the Love Canal, very high values of dioxin were reported for sump and storm sewer sediment. No values were reported for the control areas.

Table C-1.—Number of Samples Required To Detect Actual Differences Between the EDA and Control Areas

Detection rates		Number of samples/per medium to produce a 90-percent chance of detecting a statistical difference
Control	EDA	
0.03[a]	0.06[b]	625
0.03	0.09	203
0.03	0.12	110
0.05	0.10	362
0.05	0.15	115
0.05	0.20	61

[a]The frequencies of detection in control area samples was between 3 and 5 percent.
[b]Assumed detection rate in the EDA.

SOURCE: Cupples, op. cit.

Although these measures appear low, their absolute values for organic compounds can be questioned. The EPA monitoring study used 19 different analytical laboratories, each with varying capabilities.[6] NBS was asked by EPA to review the quality control protocols used in the study.[7] While NBS accepted the protocols as adequate, the Bureau could not verify the certainty associated with performance of the different laboratories. As stated in a letter to Senator A.M. D'Amato:[8]

[4]L. A. Cupples, Boston University School of Public Health, report submitted to OTA, Industry, Technology, and Employment Program, May 1983.
[5]Statements made by EPA officials during a meeting with OTA on May 12, 1983.

[6]*Environmental Monitoring at Love Canal* (Washington, D.C.: Environmental Protection Agency, vol. I, pp. 36-37.
[7]*Environmental Monitoring at Love Canal: Interagency Review*, op. cit.
[8]R. G. Kammer, letter to Senator A. M. D'Amato, August 1982.

Table C-2.—Maximum Values (in ppm) Reported for Organic Compounds

Shallow well	EDA	0.048 di-n-octylphthalate
	Control	0.150 di-n-octylphthalate
	Love Canal	3.300 3-chlorotoluene
Deep well	EDA	0.230 phenol
	Control	0.105 xylene
	Love Canal	0.050 acrolein
Soil	EDA	3.120 chrysene
	Control	0.420 benzene
	Love Canal	10.485 1,2,3,4-tetrachlorobenzene
Sump water	EDA	0.586 1,4-dichlorobenzene
	Control	0.002 Aroclor 1254
	Love Canal	8.500 2,4-dichlorophenol
Sump sediment	EDA	—
	Control	—
	Love Canal	16,523 2,4-dichlorotoluene
Storm sewer water	EDA	0.062 1,2,4,5-tetrachlorobenzene
	Control	0.0001 gammma-BHC
	Love Canal	0.120 hexachlorobutadiene
Storm sewer sediment	EDA	123.000 di-(2-ethylhexyl)phthalate
	Control	0.012 1,2-dichloroethane
	Love Canal	263.000 Aroclor 1254
Surface water sediment	EDA	20.000 delta-BHC
	Control	23.645 di-(2-ethylhexyl)phthalate
	Love Canal	—

SOURCE: U.S. Environmental Protection Agency, op. cit., vol. III.

Table C-3.—Maximum Values Reported for Dioxin, ppb

Media	EDA	Love Canal	Control area
Sump water	—	.6	—
Sump sediment	—	9570	—
Storm sewer sediment	672	329	—
Surface water sediment	37.4	—	—

SOURCE: U.S. Environmental Protection Agency, op. cit., vol. III.

> As we reported in our May 10, 1982 review, unless measured values, including non-detected, are accompanied by estimates of uncertainty, they are incomplete and of limited usefulness for further interpretation and for drawing conclusions.

EPA's response to NBS was to provide a "worst case" range for selected chemicals based on performance of the worst laboratory.[9] While this provides some idea about the variability for these particular chemicals, it does not allow estimation of confidence limits for the total set of 150 chemicals used in the study.

As mentioned in appendix B, a major failing of the EPA effort was the improper use of replicates. For most of the environmental media, no replicate samples were taken at individual sites. In those few instances where replication was obtained, EPA treated them as separate samples. Thus, there is no way to determine if the absolute values reported for any one chemical varies by twofold, tenfold, or 100-fold.

[9] *Environmental Monitoring at Love Canal: Interagency Review*, op. cit.

This concern is not trivial. All samples collected from environmental media will vary to some extent. Because of the inherent variability of ecosystems and the variations in interactions between chemicals and elements of the environment, a minimal level of uncertainty can never be overcome. An additional level of variability results during the analytical phase of a monitoring study. Such analytical variations arise when different people perform the same procedure in the same laboratory. Even greater variability is introduced when different laboratories with different capabilities, experience, and equipment* are used in the same study.

In addition to uncertainties associated with the absolute values reported for chemicals detected within the EDA, there is uncertainty associated with the detection limits of the various laboratories. Within the EDA, 90 percent of the analytical measurements were below the laboratory detection limits. The obvious question is raised. Are the low values real or could they result from limitations of the various laboratories? If detection limits were insensitive (i.e., too high), concentrations significant for potential health problems may be overlooked. If detection limits were too variable, then extent of contamination may not be accurately identified. The adequacy of EPA's reported detection limits for analytical methods is difficult to

*Although the same brand name of equipment can be used by different laboratories, performance differences between similar equipment can be expected.

evaluate, in part because of the conceptual complexity of detection limits.

Method detection limits (MDL) were used by EPA. The MDL is the lowest concentration of a substance that can be detected with a 99 percent confidence that the reported concentration is greater than zero.[10] EPA regarded detections reported as "trace" to be above the MDL for a particular analytical laboratory.[11] Therefore, the upper limit for the frequency of reporting false positive (or false negative) readings should be 1 percent, i.e., one might not be able to determine with 99 percent confidence that an undetected substance is, indeed, absent in a sample at concentrations below the MDL. OTA finds that this is subject to uncertainty.

EPA reported detection limits for only a sample of its target substances, on the grounds that this select group was representative of each structural class present among the target substances. However, it is difficult to determine whether MDLs accurately reflect routine practices of particular analytical laboratories. As EPA acknowledged, except in the case of air samples, analytical laboratories knew which samples were performance evaluation samples.[12] Performance evaluation samples could, therefore, have been analyzed more carefully than on the field samples.

Moreover, a different MDL was reported for particular substances representing more than one analytical method, and up to six analytical laboratories. In some cases, MDLs were estimated for several laboratories based on the performance of only one. These factors contribute to uncertainty about detection limits.

Reported MDLs for metals were estimates only, and were reported as aggregated value, which obscures variability among laboratories. Also, analysis for pesticides have only a single reported MDL, again obscuring laboratory variability. In contrast, a MDL for many organic substances was reported as a measured limit for specific laboratories.

Although most reported detection limits are quite low relative to health standards (where available), the issue of uncertainty of detection limits is relevant to the issue of the validity of EPA results. For example, beta-BHC is reported to have an overall (low) MDL of 0.006 ppb for analytical Method 608 in reagent water. The same substance is reported to have MDLs that range from 4.2 to 9.5 ppb using analytical Method 625. The actual value depends on which laboratory performed the analysis. Thus, if different methods or different laboratories were used to analyze for beta-BHC, then intended comparisons of frequencies of beta-BHC detections among components of the environment might represent comparisons of methods and of laboratory performance. Although, in conversation, EPA has asserted that this should not happen, no mechanism for reliably preventing it was presented. It should be emphasized that neither of these values may be relevant to detection limits of actual samples as the Love Canal samples which would contain competing contaminants that possibly lower analytical power.

Such variability in MDLs is not atypical. Detection limits for other compounds also varied widely. For example, reported MDLs for 1,2,3,4-tetrachlorobenzene ranged from 0.5 to 17 ppb, varying by a factor of 34 for different laboratories employing the same analytical method. Detection limits for several closely related substances, the alpha, beta, delta, and gamma isomers of BHC, varied from 0.004 to 0.009 ppb, a factor of 2.25. Likewise, detection limits for DDT, DDD, and DDE varied by a factor of 3 (0.004 to 0.12 ppb). MDLs for endosulfan 1, endosulfan 2, and endosulfan sulfate varied from 0.004 to 0.066 ppb (a factor of 16.5), and for heptachlor and heptachlor epoxide MDLs varied by a factor of 27.7 (from 0.003 to 0.083 ppb).

MDLs were reported for only a subset (about one-third) of the total 150 chemicals; EPA considered that the subset of compounds spanned the range of compound classes used in the study.[13] Consequently, EPA asserts that it should be possible to determine approximate detection limits for all substances:[14]

> Similarly, it is reasonable to assume that the method detection limits of most of the organic analytes . . . fall into the same range of 0.5 to 79 micrograms per liter.

Nevertheless, none are provided for substances known to have been disposed into Love Canal.

This variability in detection limits introduces uncertainties in interpreting the meaning of the many samples reported to be below the limits of detection. This uncertainty in turn casts doubt on any conclusions about the levels of contamination of the EDA or the control area.

All reported MDLs are in or below the range of 0.5 to 79 ppb. The observed variability of MDLs across methods as well as for similar compounds and the lack of MDLs for most of the target chemicals calls into question the ability to detect hazardous concentrations

[10] J. A. Glaser, et al., "Trace Analyses of Wastewaters," *Environmental Science and Technology*, vol. 15, 1981, pp. 1426-1435.

[11] *Environmental Monitoring at Love Canal*, op. cit.

[12] Statements made by EPA officials at a meeting with OTA, May 12, 1983.

[13] Deegan, op. cit., "it is true that MDL's were determined for a subset of the target compounds, and the subset included model compounds for the complete set of target compounds . . . a valid methodology . . . accepted widely in scientific research," p. 147.

[14] *Environmental Monitoring at Love Canal*, op. cit., vol. I, p. 228.

of the target substances. Were the detection limits for each compound sufficiently low and were actual laboratory performances sufficiently high to allow a conclusion that those chemicals not detected would be present in such low levels as not to pose a threat to human health? Is the range of variability for MDLs sufficiently low to be certain that estimates of variance for absolute concentrations are not within hazardous concentrations for *all* target substances? Until MDL values are reported with estimates of variances for each, uncertainties about the meaning of none detected and trace, remain.

What If EPA's Numbers Are Wrong?

Most of the samples in which EPA detected measurable amounts of chemicals revealed concentrations in the ppb range. If those numbers are accurate, the assumption can be made that the samples in which only traces of chemicals were detected or in which not even traces were detected contain even lower concentrations of chemicals. Looking at the data reported later in tables C-5 and C-6, it can be seen that if the trace measurements are in the ppb range, the levels of chemicals in the EDA are indeed so low as to pose an acceptable health risk (except for hexachlorobenzene and dioxin).

NBS was asked to comment on the amount of chemicals that might have gone undetected in EPA's monitoring program at Love Canal. NBS was not convinced that the absence of detectable levels of chemicals in the EPA analysis was consistent with concentrations as low as parts per billion.[15] Instead, it is confident that the concentration of a chemical reported to be below detection is no more than 1 part per million.

OTA asked officials of DHHS who participated in making the habitability decision if they would persist in their conclusion that the declaration area was habitable if many chemicals were present in the near 1 ppm range. The response was that they would stick by their earlier decision with a demur about certain chemicals.

OTA would not be so sanguine about the safety of the EDA if the concentration of all or most of the 150 chemicals approached 1 ppm. If the NBS estimate that the "no detectable limit" might be as high as 1 ppm is applied to monitoring of drinking water, then every limit shown on table C-5 would be exceeded in the EDA. If the conservative NBS estimate is not applied to drinking water because it is to be expected that drinking water would be cleaner than other waters and soils, finding concentrations in the 1-ppm range in other media would still show that contamination of the EDA was widespread. In that case, the chance of human exposure would have to be reckoned as substantial.

Some toxic chemicals exhibit "synergism," i.e., the toxic effect of simultaneous or sequential exposure to two (or more) chemicals greatly exceeds the toxic effects predicted from adding together the effects of the individual chemicals. Without consideration of synergism and with consideration of only additive effects of chemicals, OTA would not consider the EDA habitable if many of the 150 chemicals were present at concentrations near 1 ppm. For instance, if 10 carcinogens are present in concentrations such that each one poses a 1 in 100,000 chance of a person developing cancer, then the 10 together may pose a 1 in 10,000 risk, which may well be so high as to be unacceptable. For the very reason that so little is known about carcinogenic potentials and other toxic potentials, OTA would come to the conclusion that the uncertainties about health effects from many chemicals being present at near 1 ppm each would preclude considering the declaration area to be habitable.

However, it is impossible to interpret the NBS opinion as supporting the idea that all chemicals for which MDLs were reported might be present in concentrations near 1 ppm. First, the ability of laboratories to detect chemicals varies from substance to substance. The basis of the NBS conclusion, that no concentrations higher than 1 ppm would have gone undetected must be based on consideration of the properties of the chemicals most difficult to detect and measure. Therefore, the MDLs for chemicals that are more easily detectable must be lower, perhaps in the low ppb range claimed by EPA. The second reason is that there is little reason to believe that all 150 chemicals monitored by EPA were actually present in significant amounts in the Love Canal dump. Therefore, to assume that all the 150 chemicals could be present at concentrations of up to 1 ppm poses an immediate question about the origin of all these chemicals. OTA's concentration on a subset of chemicals known to be present in the landfill eliminates the problems associated with assigning a possible concentration to chemicals that are not present.

It would be a tedious task for EPA to supply estimates of variance to support the contention that all MDLs were in the low ppb range. However, it might be a manageable job for EPA to examine the records for the 16 or so chemicals known to be in the landfill in significant amounts. Because the argument about possible health effects hangs on knowing the absolute concentations of chemicals in the EDA, further analysis of the EPA data seems worthwhile.

[15]Krammer, op. cit.

Uncertainties in Potential Health Effects

Adverse health effects from exposures to toxic substances are convieniently divided into two broad groups: acute and chronic. *Acute* effects are observed soon after exposure, typically to relatively large concentrations of toxic materials. For example, when a ruptured train car spilled nitric acid and the wind carried fumes into residential areas of Denver, Colo., people experienced choking and difficulty in breathing. Less spectacular and more common effects include eye irritations from air pollutants during periods of poor air quality.

Acute toxic effects are marked by the body's responding to an insult from ingestion, inhalation, or dermal exposure to a substance. When the insult is removed, the affected cells and organ systems of the body may recover, may die, or may be replaced. Importantly, new body cells, those formed after the insult has passed, are not affected.

Chronic toxic effects encompass three dread events: mutations, cancer, and birth defects. These may result from exposure to extremely low concentrations and may not be observed until years after the exposure occurred. (Neurological disorders, which may be caused by low doses of some materials, e.g., lead, are also chronic health effects, but they are not discussed in this paper.) Mutations and cancer differ from acute toxic effects in that cells are altered genetically and the damage caused is perpetuated in progeny cells formed from the one originally harmed. In contrast, birth defects that result from in utero exposure of the fetus to chemicals do not necessarily involve genetic alterations. Some may result from biochemical changes in critical developmental processes. Because most concerns about health risks to EDA residents has centered on chronic effects, the OTA review focused on mutations, cancer, and birth defects.

Mutagenesis and Cancer

Mutagenesis—the causation of mutations—is the best understood chronic effect, from the standpoint of mechanism. An environmental contaminant interacts with the DNA of a germ (reproductive) cell and alters the genetic information within it. If that germ cell, an egg or a sperm, is involved in the formation of an organism, every cell in the new organism will bear the alteration, the mutation. If this organism has progeny, half of those progeny, on average, will bear the mutation. Thus, mutations are chronic in the sense that once introduced into a population they may be propagated in every succeeding generation. Some mutations are beneficial, but most of those that are detected in humans are associated with deleterious effects.[16]

Cancer also involves an interaction between a contaminant and DNA, but the mutational event occurs in a somatic, or body, cell rather than in a germ cell. Thus, the mutation is not passed on to the next generation. Instead, a mutation that results in cancer causes rapid proliferation of cells. The rapidly growing cells, all of which may derive from a single mutated cell, in turn, produce a tumor.[17]

Many mutational events, whether they occur in somatic or germ cells, may have no effect because they cause changes in DNA without biological consequences. Others may produce small but undetected changes, either beneficial or detrimental. Although it is likely that only a few DNA changes produce a detectable mutation or tumor, our awareness of mutational events in humans has been heightened by increasing knowledge of their sometimes devastating effects.

Methods for Identifying Health Effects

During recent years, much effort has been expended in identifying carcinogens, agents that cause cancer.[18] The methods used for identifying cause-effect relationships between manmade or natural substances and toxic effects in humans can be illustrated by a discussion of the methods used to identify carcinogens. Effects from carcinogens (and toxic substances, in general) can be identified through results of epidemiology—the study of diseases and their causes in human populations—and various laboratory tests.

Epidemiology is the only method that establishes associations between a substance and human toxicity. However, it is limited as a technique for identifying chronic effects that appear years or decades after exposure, because people are difficult to study, move from place to place, change their work environment, and change their living habits. Also, it is hard to locate those people who may have been exposed to a particular carcinogen several years previously. Estimating past exposures to suspect agents is very difficult.

Testing suspected chemicals in laboratory animals, generally rats and mice, is the backbone of current toxic substances identification. A chemical is administered to animals either in their food, water, air, or (less frequently) by force feeding, skin painting, or injection.

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[16]For examples see *The Role of Genetic Testing in the Prevention of Occupational Disease* (Washington, D.C.: U.S. Congress, Office of Technology Assessment, OTA-BA-195, April 1983).

[17]*Assessment of Technologies for Determining Cancer Risks From the Environment* (Washington, D.C.: U.S. Congress, Office of Technology Assessment, OTA-H-138, June 1981.

[18]Ibid.

The animals are observed over a specified time period to identify acute or chronic effects.

The reliability of animal tests, bioassays, depends on their design and execution. Guidelines for cancer bioassays were published by the National Cancer Institute in 1976. Bioassays now cost between $100,000 and $1 million and require up to 5 years to complete. Clearly such expensive tools can be used only to test highly suspect chemicals, and much effort is devoted to selecting chemicals for testing.

Molecular structure analysis and examination of basic chemical and physical properties are used to make preliminary decisions about the likelihood of a chemical being toxic and whether or not to test it. For instance, greater suspicion is attached to chemicals that share common features with identified toxic substances. "Paper chemistry" and "paper toxicology" are used most extensively to estimate properties of new chemicals.[19] Unfortunately, not all chemicals within a single structural class behave similarly; thus, limits are placed on the use of these approaches.

New developments in laboratory testing has resulted in the greater use of short-term (a few days to months) tests. Test costs range from a few hundred dollars to a few thousand. Such tests depend on measuring biological interactions between chemical and DNA. The best known test, the "Ames test," measures mutations in bacteria. Other short-term tests use nonmammalian laboratory animals, as well as cultured human and animal cells. Some tests measure mutagenicity; others measure either the capacity of a chemical to alter DNA metabolism or to transform a normal cell into one with abnormal growth characteristics. Problems in interpreting mutagenicity tests arise from the ease of doing them; the possibility of false-positive tests increases with the number of tests that are done, and since negative tests frequently are not reported, there is some danger of overrelying on positive test results. Further complicating interpretation, a substance may test out as a mutagen in one assay system and not in another.

A critical problem in estimating human health effects is the need to extrapolate results from studies involving large concentrations of chemicals to expected results from exposure to low levels actually seen in the environment. The idea of dose response (that the percentage of people suffering adverse effects will decrease at lower exposures) is well accepted. However, the exact relationship between dose (exposure levels) and responses (numbers of affected people) is disputed. In particular, some knowledgeable observers argue that there are doses of chemcials so low that they will cause no disease. In other words, a threshold has to be exceeded before any adverse effects will be seen. In general, thresholds are better accepted for acute effects than for chronic effects. In particular, if the interaction between a single molecule of a chemical and DNA is sufficient to produce a mutation, no threshold value is likely for mutagenic and carcinogenic effects.

The problems of extrapolation are more complex when data from laboratory studies are the only available information. In those cases, a method must be chosen to translate the meaning of a toxic effect in the animal to an expected toxic effect in humans. Almost everyone accepts that animal results are important to predicting human effects; toxicology is based on that premise. However, there can be endless arguments about the applicability of a particular animal test.

A 1979 IARC report summarized the agency's analysis of 354 chemicals and chemical processes that it had reviewed in its program, which began in 1971.[20] IARC found sufficient epidemiologic information to evaluate carcinogenicity in humans for fewer than 100 chemicals. For 18 of those, IARC considered that the evidence was sufficient to support a conclusion that the chemical causes cancer in humans. For an additional 18, the evidence was sufficient to support a conclusion that the agent was a probable human carcinogen. In the cases of the remaining 318 chemicals and chemical processes, the data from human studies were insufficient to support a conclusion that the substance or process is a human carcinogen or a probable human carcinogen.

IARC also reviews the worldwide literature about the testing of chemicals for carcinogenicity in animals. About animal tests, it says:

> . . . in the absence of adequate data in humans it is reasonable, for practical purposes, to regard chemicals for which there is *sufficient evidence* of carcinogenicity (i.e., a causal association) in animals *as if they presented a carcinogenic risk for humans.*

IARC has reviewed the literature about the testing of 354 chemicals in animals. For 142 of those, IARC considered that the animal evidence was "sufficient," and that those substances should be considered to pose a carcinogenic risk for humans. In 1980, scientists at the National Cancer Institute (NCI) reviewed all of the cancer tests carried out in animals there.[21] In the cases where both IARC and NCI evaluated data about the same chemicals, the results of the two organizations' analysis were generally consistent.[22]

[19]OTA, *The Information Content of Premanufacture Notice*, OTA-BP-H-17, Government Printing Office, Washington, D.C.: 1985.

[20]*Chemicals and Industrial Processes Associated With Cancer in Humans*, Monographs, Supplement 1, (Lyon, France: IARC, 1979).

[21]R. A. Griesemer and C. Cuets, Jr., "Toward a Classification Scheme for Degrees of Experimental Evidence for Carcinogenicity of Chemicals for Animals," in *Molecular and Cellular Aspects of Carcinogen Screening Tests*, H. Bartsh and L. Tomatis (eds.), Lyon France, 1980.

[22]OTA, 1981, op. cit.

Comparing the relatively small number of chemicals for which human evidence is available to the larger number of chemicals which has been tested in animals illustrates the importance of animal tests. The number of tested chemicals is much smaller than the number of all chemicals, and there are major efforts underway to use "short-term tests," most of which measure mutagenicity to provide information about carcinogenicity.

The IARC review provides an example of scientists and policymakers wrestling with the problems of extrapolating results of epidemiology and animal tests about toxicity to estimates of human effects. Although findings of IARC are not binding on governments, they are generally accepted as authoritative and provide an example of a successful ongoing effort to evaluate scientific evidence. A number of approaches to evaluating evidence about carcinogenicity and other toxicities for regulatory purposes, all of which involve a centralized panel of experts to consider the toxicity of substances, have been advanced by Government agencies,[23] Members of Congress, and by trade associations.[24] A recent National Academy of Sciences committee document argued against a central committee for making decisions about carcinogenicity for all Government agencies, but urged that a central committee be formed and charged with developing guidelines for making those decisions.[25]

To a major extent, the interest in expert review stems from a desire to grapple with uncertainty. Uncertainties in estimating the hazards posed by chemicals result from difficulties with test design and execution, the scantiness of data, and methods for extrapolation. The activities of an expert panel (e.g., IARC) to review data and conclusions reduce the uncertainties in a few cases involving carcinogenicity. In the absence of such expert review, the reader or scientist interested in toxicity must develop a critical eye, inspect and evaluate the evidence presented by others, and discuss opinions with other interested parties.

Health Effects Associated With Love Canal Chemicals

Toxic effects associated with 18 chemicals known to have been deposited in the canal landfill are listed in table C-4. The minimum lethal doses for these chemicals are much greater than environmental concentrations reported or expected within the EDA (see tables C-5 and C-6). For example, maximum environmental concentrations of chlorobenzene were on the order of 3 to 5 micrograms per cubic meter of air (table C-6), an amount less than 1/1,000,000 the level needed to kill the most sensitive laboratory animal (table C-4).

Data for birth defects or reproductive effects (called here "teratogenic effects") are not available for most of these compounds. Only pentachlorobenzene and hexachlorobenzene were reported to have been tested for teratogenicity.[26] Both were found to be positive in at least one test, but the quality of the data was not evaluated.

Mutagenic test results are reported on 12 of the substances, and of these, 8 were positive in at least one test. In addition, additional mutagenicity tests are planned for lindane and hexachlorobenzene.[27] The chemical 1,4-dichlorobenzene provides an example of a chemical that was mutagenic in one test and not in another. It has been shown to cause mutations in bacteria, but not in a test involving the use of Chinese hamster ovary (CHO) cells. Nevertheless, whatever caveats are attached to finding a positive response in testing for a mutational effect, the finding serves to warn of a possible hazard.

The fact that IARC found adequate animal data to evaluate the carcinogenicity of five of the chemicals listed in table C-4 indicates that there had been concern about the carcinogenicity of those chemicals. In addition, five chemicals, including three of the IARC-reviewed chemicals, are currently under test at the National Toxicology Program (NTP). In other words, 7 of the 18 Love Canal chemicals have been tested or are being tested for carcinogenicity. This level of effort does not mean that many or most of the chemicals are carcinogens, but it does mean that scientists have expressed sufficient concern about them that tests are necessary to provide more information.

For three of the five chemicals that IARC reviewed, data were sufficient to conclude that the chemicals are carcinogenic in laboratory animals. In the other two cases, IARC reached the conclusion that there was "limited" evidence rather than "sufficient" evidence to support a conclusion that the chemicals were carcinogens.

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[23]OSTP, "Identification, Characterization, and Control of Potential Human Carcinogens: A Framework for Federal Decision-Making," *J. National Cancer Institute*, 64:169-176, 1980.

[24]*AIHC Proposal for a Science Panel* (Searsdale, N.Y.: AIHS, 1980).

[25]National Research Council, *Risk Assessment in the Federal Government: Managing the Process* (Washington, D.C.: National Academy Press, 1983).

[26]The Department of Health and Human Services, *Report of the Subcommittee on the Potential Health Effects of Toxic Chemicals Dumps of the DHEW Committee to Coordinate Environmental and Related Programs*, undated.

[27]National Toxicology Program, *National Toxicology Program: Fiscal Year 1983 Annual Plan*, Research Triangle Park, N.C., 1982.

Table C-4.—Summary of Test Results Available on Health Effects of Chemicals Disposed in Love Canal and Monitored by EPA

Substance	Minimum lethal dose[a]	Mutagenicity[b]	Carcinogenicity[c]	Regulation or standard[d]		
				ACGIH	OSHA	EPA
Lindane (gamma-hexachlorohexane)	Ingestion, animal, 180 mg/kg	Cytogenic changes to be tested (NTP) negative (CCERP)	Animal + (IARC) Animal - (NCI)	Yes	Yes	National Drinking Water Standard W.Q.C.[e]
Chlorobenzene	Inhalation, animal, 15 g/m³	—	Under test (NTP)	Yes	Yes	W.Q.C.
1,2-Dichlorobenzene	Inhalation, animal, 821 ppm	Positive (CCERP)	Animal ? (IARC) Animal - (NTP)	Yes	Yes	W.Q.C.
1,3-Dichlorobenzene	—	Positive (CCERP)	—	—	—	W.Q.C.
1,4-Dichlorobenzene	Man, 221 mg/kg	Point mutagen, negative, CHO test (NTP)	Animal ? (IARC) Under test (NTP)	Yes	Yes	W.Q.C.
1,2,3-Trichlorobenzene	—	Negative (CCERP)	—	—	—	W.Q.C. insufficient data
1,2,4-Trichlorobenzene	Ingestion, animal, 756 mg/kg	Negative (CCERP)	—	Yes	—	W.Q.C. insufficient data
1,3,5-Trichlorobenzene	Implant, animal LD_{50} 20 mg/kg	Negative (CCERP)	—	—	—	W.Q.C. insufficient data
1,2,3,4-Tetrachlorobenzene	—	—	—	—	—	W.Q.C.
1,2,4,5-Tetrachlorobenzene	Ingestion, animal, 1,035 mg/kg	Positive (CCERP)	—	—	—	W.Q.C.
Pentachlorobenzene[f]	Ingestion, animal, 2,000 mg/kg	Positive, CHO (NTP)	Under test (NTP)	—	—	W.Q.C.
Hexachlorobenzene[f]	Man, 220 mg/kg	Positive (CCERP) to be tested (NTP)	Animal + (IARC)	—	—	W.Q.C.
2-Chloronaphthalene	Ingestion, animal 886 mg/kg	—	—	—	—	W.Q.C. insufficient data
Alpha-Chlorotoluene	Ingestion, animal, LD_{50} 1,200 mg/kg	Point mutagen DNA replication positive (CCERP)	Animal + (IARC) Under test (NTP)	Yes	Yes	
2-Chlorotoluene	Inhalation, animal, 175,000 ppm			Yes	Yes	—
3-Chlorotoluene	—		—	—	—	—
4-Chlorotoluene	—	Negative (CCERP)	—	—	—	—
2,4-Dichlorotoluene	—		—	—	—	—

[a]All data in this column are from *1980 Registry of Toxic Effects of Chemical Substances* (NIOSH, 1982).

[b]References for data in this column are from NIOSH (1982) unless otherwise indicated: NTP is *National Toxicology Program: Fiscal Year 1983 Annual Plan* (NTP, 1982); and CCERP is *Report of the Subcommittee on the Potential Health Effects of Toxic Chemical Dumps of the DHEW Committee to Coordinate Environmental and Related Programs* (Department of Health and Human Services, undated).

The appearance of a test name means that the chemical was found to cause the named effect: *cytogenic changes:* microscopically visible chromosomal changes; *point mutagen:* chemical altered a specific gene in the test organism, a standard test; *CHO test:* a test of the capacity to alter growth patterns of Chinese hamster ovary cells, a standard test; *DNA replication:* a test of the capacity to alter DNA replication, a standard test; *positive:* CCERP reported that at least one test has shown the chemical is a mutagen; the quality of the data was not reviewed; and *negative:* CCERP reported that the chemical had been tested and none of the results showed the chemical to be a mutagen; the quality of the data was not reviewed.

[c]References: IARC is *IARC Monographs Supplement 1* (IARC, 1979); NCI is R. A. Griesemer, and C. Cueto, Jr. in *Molecular and Cellular Aspects of Carcinogen Screening Tests* (IARC, 1980); and NTP is same as under (b). + means the agency judged the substance to be an animal carcinogen; ? means the evidence about carcinogenicity was limited; and - means the evidence was negative.

[d]Acronyms: ACGIH—American Council of Government Industrial Hygienists, OSHA—Occupational Safety and Health Administration, EPA—Environmental Protection Agency, IARC—International Agency for Research on Cancer, NCI—National Cancer Institute, and NTP—National Toxicology Program.

[e]W.Q.C.: Water Quality Criteria Document (45 F.R., 11/28/80). W.Q.C. means EPA recommended a standard; W.Q.C. insufficient data means that there were insufficient data to base a standard.

[f]At least one test result indicates that this substance has teratogenic properties.

Table C-5.—Comparison of Regulated Exposure Limits to Detected Maximum Concentrations in the EDA: Water

Substance	Regulated limit (exposure through ingestion)	Maximum concentration found in EDA[a] [concentration (medium)]	Ratio: maximum detected level/ standard
One substance regulated under National Drinking Water Standard:			
Lindane	4.0 ppb[b]	5.3 ppb (sanitary sewer)	1.3
		3.4 ppb (storm sewer)	0.85
Substances for which water quality criteria have been published:			
Lindane	No safe limit (carcinogen)		
	10^{-5} risk,		
	water and fish, 0.186 ppb	5.3 ppb (sanitary sewer)	28.5
		3.4 ppb (storm sewer)	18.3
	fish only, 0.625 ppb	5.3 ppb (sanitary sewer)	8.5
		3.4 ppb (storm sewer)	5.4
Chlorobenzene	488 ppb	Trace[c] (shallow well)	
1,2-Dichlorobenzene	400 ppb	15 ppb (deep well)	0.04
1,3-Dichlorobenzene	400 ppb	80 ppb (sump)	0.2
1,4-Dichlorobenzene	400 ppb	586 ppb (sump)	1.46
1,2,4,5-Tetrachlorobenzene	Water and fish, 38 ppb	62 ppb (storm sewer)	0.61
	fish only, 48 ppb	62 ppb (storm sewer)	0.77
Hexachlorobenzene	No safe limit (carcinogen)		
	10^{-5} risk,		
	water and fish, 7.2 ppt[b]	Trace (sump water, sanitary sewer)	
	fish only, 7.4 ppt	Trace (sump water, sanitary sewer)	

[a]Much higher concentrations, sometimes in excess of 10,000 ppb, were found in surface water sediment near sewer outfalls and in sewer sediments. Those two contaminated media are to be cleaned up in the remediation process.
[b]ppb: parts per billion, 1 μg of chemical/liter water; ppt: parts per trillion, 0.001 μg of chemical/liter water.
[c]Trace: detectable, but not measurable concentrations.

SOURCE: From several published sources.

Table C-6.—Comparison of Regulated Exposure Limits to Detected Maximum Concentrations in the EDA: Air

Substance	Regulated exposure limit[a] (exposure through inhalation)	Maximum concentration found in EDA [concentration (medium)]	Ratio: maximum detected level/ standard
Lindane	500,000 μg/m³ (OSHA, ACGIH)[b]	0.098 μg/m³ (living area)	<0.001
Chlorobenzene	350,000 μg/m³ (OSHA, ACGIH)	3.5 μg/m³ (basement)	<0.001
1,2-Dichlorobenzene	300,000 μg/m³ (OSHA, ACGIH)	68 μg/m³ (living area)	<0.001
1,4-Dichlorobenzene	450,000 μ/m³ (OSHA, ACGIH)	25 μg/m³ (living area)	<0.001
1,2,4-Trichlorobenzene	40,000 μg/m³ (ACGIH)	Trace[c] (living area)	<0.001
2-Chlorotoluene	250,000 μg/m³ (ACGIH)	8 μg/m³ (living area)	<0.001

[a]Limits are generally expressed in units of milligrams/cubic meter. To facilitate comparison of limits and maximum concentrations, limits are converted to units of micrograms/m³ here.
[b]OSHA—Occupational Safety and Health Administration; ACGIH—American Council of Government Industrial Hygienists.
[c]Trace: detectable, but not measurable concentrations.

SOURCE: From several published sources.

The National Cancer Institute's (NCI) evaluation of the carcinogenicity of lindane differed from that of IARC.[28] Data from NCI did not support the idea that it is an animal carcinogen. IARC concluded that lindane was a carcinogen.

For 1,2-dichlorobenzene, IARC found that there was only limited information about carcinogenicity. A subsequent test by NTP reveals that the substance does not cause cancer in either rats or mice. Therefore, ad-

[28]Griesemer, op. cit.

ditional evidence has reduced the level of concern about possible carcinogenic effects for that chemical. A related chemical, 1,4-dichlorobenzene is now under test at NTP as is alpha-chlorotoluene. Data about the carcinogenicity of chlorobenzene and pentachlorobenzene under test at NTP, have not been reviewed by IARC.

Table C-4 also shows that workplace and environmental exposures to many of these chemicals are regulated. The Occupational Safety and Health Administration (OSHA) regulates workplace exposure, and restrictions on workplace exposures have been recommended by a group of industrial health experts, the American Conference of Government Industrial Hygienists (ACGIH). EPA has published water quality criteria for 13 of the 18 chemicals. In addition, a National Drinking Water Standard regulates exposure to lindane.

The data summarized in table C-4 show that the chemicals deposited in the canal landfill include some recognized as presenting hazards to human health. An immediate objection to drawing any conclusions about health effects from these chemicals at Love Canal derives from EPA's observations that the concentrations within the EDA were very low.

Comparison of Regulated Exposure Levels and Environmental Concentrations

EPA has published National Drinking Water Standards for 16 inorganic chemicals, 6 pesticides (including lindane), 1 group of organic chemicals, and total dissolved solids. As is shown on table C-5, the maximum concentration of lindane found in one sample each from sanitary sewers and storm sewers slightly exceeded that limit. It should be emphasized that while this concentration is higher than the *drinking* water standards, the water in both systems is not likely to be ingested by humans.

Water quality criteria documents have been published for 64 chemicals to serve as guidelines for acceptable concentrations in drinking and fishing waters. There was some emphasis on protecting against carcinogenic risks in the criteria documents, and, in keeping with the idea that there is no dose of a carcinogen below which there is no risk, the Agency declared that there was no safe limit for carcinogens. Instead, it calculated the amount of the substance, that if ingested over the course of a lifetime, would cause an incremental risk of cancer equal to 1 case of cancer in 100,000 people. The magnitude of that risk can be judged by comparison to the figure that about 20 percent of Americans (or 20,000 out of every 100,000) die from cancer. As is shown in table C-6, the maximum detected concentrations of lindane in sewers exceeded the standards for water to be used for *drinking or fishing*. The measured levels of 1,2- and 1,3-dichlorobenzene and 1,2,4,5-tetrachlorobenzenes were less than the limits established by the water criteria documents. Only 1,2-dichlorobenzene, found at 0.04 of the recommended guideline, was detected in deep wells and likely would be associated with human ingestion. No numerical measurements were reported for chlorobenzene and hexachlorobenzene, and EPA claims that concentrations of those chemicals would be in the low ppb range. If the concentrations are that low or lower, the level of chlorobenzene would be below that recommended by EPA.

Hexachlorobenzene presents an analytical problem. The water quality criteria document associates a 10^{-5} cancer risk with a 7 ppt concentration of hexachlorobenzene. However, that chemical cannot be measured at concentrations lower than a few ppb. Thus, hexachlorobenzene could be present in water samples in the Love Canal study in concentrations up to 1 ppb, 130 times the level associated with a 10^{-5} cancer risk. But such concentrations are possible in all water; methods are not available to measure this chemical at 7 ppt. The fact that hexachlorobenzene was detected only in waters that humans do not drink or fish means that opportunities for exposure are limited.

To summarize, measured concentrations of some chemicals found in sewer and sump waters in the EDA approached or exceeded levels recommended for drinking and fishing waters. However the contaminated waters in the EDA are not likely to be consumed, and exposure through ingestion is unlikely.

OSHA or ACGIH or both have established limits on workplace exposure to six of the chemicals. In the workplace, concern is about exposure by inhalation or through the skin. In the case of lindane, the exposure limit shown on table C-6, based on inhalation, is to be further lowered if there is any chance of the chemical reaching the worker's skin. The workplace exposure limits are based on consideration of acute toxic effects and are designed to protect against workers' becoming ill soon after exposure. They are not designed to protect against any chronic health effect—cancer, birth defects, or mutations. Therefore, it is no surprise that the maximum levels of airborne contamination found in the EDA is much less than the workplace limits. Although there is little reason to believe that the workplace limits protect against chronic health risks, the airborne concentrations at Love Canal are much lower, and are as low as levels detected in many areas of the country.

EPA can consider chronic health effects in setting limits for air pollutants under the Clean Air Act. To

date, it has not published nor made public any consideration of possible regulations of the chemicals listed in table C-6. Therefore, there are no standards or guidelines to compare to the detected levels. EPA did compare airborne concentrations of chemicals in the Love Canal area to concentrations in cities around the country, and there were no striking differences reported.

The Special Case of Dioxin

Dioxin (more precisely, 2,3,7,8-tetrachlorodibenzo-p-dioxin, or 2,3,7,8-TCDD, or TCDD) is one of the most toxic substances. It is known to cause cancer in laboratory animals, and it has been associated with tumors in humans. The "buyout" of Times Beach, Mo., was based on the premise that dioxin present at concentrations greater than 1 ppb in the soil presented a health threat.

There is no Federal standard that restricts environmental exposure to dioxin. EPA has carried out an assessment of the health risk posed by the presence of dioxin in incinerators. The Agency concluded that 0.0004 micrograms/m^3 of stack air, which would be diluted 100,000-fold by the time it reached ground level, where it might be inspired, would not "present a public health hazard."[29] The government of the Providence of Ontario has set a permissible limit for dioxin in air equal to 0.00003 micrograms/m^3, which is about 1/10 the level found by EPA in the incinerator stacks. (An average person breathes about 20 m^3 of air daily. Over a 70-year lifetime, a person breathing the maximum limit permitted by Ontario would inhale 219 micrograms of dioxin.)

One of the surprises from Times Beach is the observation that dioxin is very stable in soil. The stability is probably related to the fact that dioxin binds very firmly to particles in the soil, and being bound protects it from degradation. It is so difficult to extract dioxin from soil, that it may be that the chemical is not removed from soil particles that are inhaled or ingested. If that is the case, soil-bound dioxin would pose little threat to human health. NTP is currently conducting studies about the bioavailability of soil-bound dioxin and expects to have results by the end of the summer of 1983. It has already been reported that root crops, such as carrots, that were grown in dioxin-containing soil did not take up appreciable quantities of dioxin.[30] The low levels found with the carrots might have resulted from contaminated soil sticking to the outside of the root.

EPA has been working on a water quality criteria document for dioxin for some time. Although it is not known what level the final document will recommend, a draft suggested that dioxin levels should not exceed 1 part in 10^{16} parts of water. This very low concentration presents analytical difficulties. Although both EPA and the Canadian Government have perfected methods to measure low levels of dioxin in water, the minimum detection level are now 100-fold higher, about 1 part of dioxin in 10^{14} parts of water. In other words, water with no detectable levels of dioxin might harbor 100 times the concentration that may be recommended as a guideline to protect health. (See discussion above, also of hexachlorobenzene.)

EPA claims that it was able to detect 1 to 20 ppt (0.001 to 0.020 ppb) dioxin in the samples taken at Love Canal. OTA has serious reservations about the intensity of sampling for dioxin, but laying those aside for the moment, EPA reported dioxin in sumps in the Love Canal homes and in storm sewers. The Agency reported finding no dioxin in air, which is not surprising because it has not been reported in air except in stack gases. And no dioxin was reported in waters. The Ring 1 homes are not being considered for rehabitation, and the storm sewers are to be cleaned up as part of the remediation effort. Therefore, the known sources of exposure to dioxin are going to be eliminated.

OTA is concerned that few samples were analyzed for dioxin in the EPA study. If the decision is made to rehabitate the EDA, and, if, as part of that effort, monitoring is carried out, dioxin should be included as a monitored substance more frequently than it was in the EPA study reported in 1982. It may be that there are good reasons for the sketchy sampling carried out earlier, but it would not reassure the public to sample this important contaminant any less frequently than other chemicals.

Studies of Health Effects in the Love Canal Population

Although the habitation decision was based on consideration of the extent of chemical contamination in the EDA, there are other data that also bear on the question of health effects. Those data derive from observations made on the population of people who lived near the Canal. *Love Canal, A Special Report to the Governor and Legislature,* in 1981 summarizes evidence collected by New York Department of Health officials until that time.[31]

[29]D. Barnes, U.S. EPA, personal communication, May 1983.
[30]R. Kimbrought, Center for Disese Control, Atlanta, Ga., personal communication, May 1983.

[31]NYS/DOH, *Love Canal, a Special Report to the Governor and Legislature,* 1981. See also, *Love Canal: Public Health Time Bomb,* NYS/DOH, 1979.

Briefly, pregnant women who lived near the canal were found to be at greater risk of suffering a miscarriage or of delivering a "low birth-weight baby." More focused research into the location of residences associated with these adverse effects revealed that the women at greatest risk lived either on 99th Street, directly adjacent to the canal, or in formerly wet areas just east of the canal. The New York State analysis of these data led to the conclusion that the frequency of spontaneous abortion (miscarriage) reached a peak in the 1960's and early 1970's. In addition, the percentage of children born with birth defects was larger among those delivered by women who lived on 99th Street or in formerly wet areas as compared to women who lived beyond what is now the declaration area. The excess of birth defects was not, however, statistically significant. (Neither the study of reduced birth weight nor birth defects has been published in a peer-review scientific journal.)

Cancer rates of residents of the census tract in which Love Canal is located have been compared to cancer rates in other census tracts in Niagara Falls. The female population around Love Canal was found to have experienced twice the number of respiratory cancers as a control female population; the excess among men was less, respiratory cancer among male Love Canal census tract residents was 1.7 times that observed in the control population.[32] Scientists differ in what importance to attach to excesses of cancer that are less than 2, but most agree that a twofold excess, as was seen for respiratory cancer in women, merits attention. Further analysis showed that the incidence of respiratory cancer within the Love Canal census tract does not vary with distance from the canal, which weakens the argument that substances in the canal were associated with the excess cancers. The incidence of some cancers, lymphoma, leukemia, and liver cancer among men living in the Love Canal census tract was only half that observed in the control areas. The incidence of genital organ and urinary cancers among women was lower among Love Canal area residents than among women in other areas of Niagara Falls.

Any conclusions to be drawn from the study of cancer incidence around Love Canal are weakened by the small number of cancers that occurred during the period (1966-77) over which the study was conducted. Furthermore, since cancers may develop years or decades after exposure, the study done by New York State may have been too early to detect an effect, if there is one. A better answer to whether or not living near the canal is associated with higher cancer rates may become available as more people who lived in the canal area are located and studied.[33]

In May of 1983, the DHHS released a study of chromosomal abnormalities in a small population of people who had lived near the canal.[34] The results of that study were negative; that is, the frequency of unusual chromosomes among the canal area residents was no greater than the frequency found in a control population. There are some problems with this study. (There may never have been a study without some problems.) In particular, in the opinion of many scientists, a chromosomal abnormality caused by exposure to toxic chemicals may be short lived and may be repaired over time. Therefore, since the exposures occurred years ago, there might be no discernible effect from them now. Despite that reservation (so far as OTA can determine, that reservation is based on technical opinion and not upon prolonged observation of human populations) and other technical reservations, the consensus is that the study does not show any chromosomal abnormalities as a result of living near Love Canal. This negative study provides evidence that an earlier study, which detected a high frequency of chromosomal abnormalities among Love Canal area residents might have been in error.

Also in May 1983, Beverly Paigen and coworkers presented a paper at a meeting of the Society for Pediatric Research.[35] They compared health effects observed in the population of people who had lived in the EDA to effects observed in groups of people who lived in control areas. They reported that low birth-weight babies were more common among the EDA population and that the average weights of babies born there were lighter at each week of gestation. Furthermore, children born and raised (for at least 75 percent of their lives to date) in the EDA were shorter than children in the control areas, and the parents reported that these children had more episodes of six different medical complaints than control area children.

Paigen confirmed that low birth weights were confined to families who had lived in the formerly wet parts of the declaration area.[36] The medical complaints in children were not restricted to families living in the wet areas, but decreased with distance from the canal. She thinks that the play of children might bring them into closer contact with contaminated areas, and dis-

[32]Janerich, et al., "Cancer Incidence in the Love Canal Area," *Science* 212, 1981, pp. 1404-1407.

[33]C. W. Heath, Jr. *Assessment of Health Risks at Love Canal,* presented at the Fourth Annual Symposium on Environmental Epidemiology, Pittsburgh, Pa., May 1983.

[34]C. W. Heath, Jr., et al., *A Study of Cytogenetic Patterns in Persons Living Near the Love Canal,* Center for Disease Control, Atlanta, Ga., May 1983.

[35]B. Paigen, et al., *Growth and Health in Children Living Near a Hazardous Waste Site,* presented at Society for Pediatric Research, May 1983.

[36]B. Paigen, Children's Hospital, Oakland, Calif., personal communication, May 1983.

tance from the canal would decrease the frequency of the children reaching such areas.

To accumulate the data in the paper was difficult. The 220 births reported in the declaration area and the 697 in the control areas occurred over a 15-year interval. Analyzing such data requires careful attention to detail, and reviewing the data and analysis requires an opportunity to review details. At the present time, the results presented by Paigen, et al., are being prepared for publication, and final evaluation of their work must wait until the paper, with more detailed descriptions of the study and data, is complete.

A major study of health effects is expected sometime this fall. The NYS/DOH has located as many as possible of all the people who lived in the canal area since the 1940's.[37] Those people were interviewed about their health status, and the results of that study will provide important information about the health of former residents of the Love Canal region, and current and former residents of the EDA.

The completed studies are sufficient to show that the Love Canal population has not experienced any adverse health effects at rates more than twice those experienced by control area populations. Spontaneous abortions and low birth-weight babies were statistically more frequent among the populations in the Love Canal region, and birth defects, although not statistically more frequent, were observed more often in that population. The incidence of some cancers in the area has been higher than in control areas; the incidence of other cancers has been lower.

As more data become available in the near future, it may become possible to draw firmer conclusions about the health impacts of living near Love Canal. Unsatisfying as it is, the consensus of opinion probably is that the studies of the Love Canal area population have produced more leads to follow up than strong conclusions about the safety of the EDA. Evidence is more convincing that serious health effects were associated with living in the Love Canal homes.

[37] N. Vianna, NYS/DOH, personal communication, May 1983.

Appendix D

Analysis of the EPA Data

Summary

OTA examined a subset (20 chemicals) of the EPA monitoring data. Differences were noted in frequencies of detection for this subset between the emergency declaration area (EDA) and control areas. Four chemicals (1,2- and 1,3-dichlorobenzene and 2- and 4-chlorotoluene) were found to be present in the EDA at greater frequencies than the control areas. The differences were significant, but the concentrations were low.

Statistical Analysis of Indicator Substances

OTA disaggregated the Environmental Protection Agency (EPA) monitoring data to allow an examination of a subset of "indicator substances," toxic chemicals known to have been disposed in the canal landfill. Twenty chemicals were identified for the OTA analysis; only 16 of them had sufficient data. Frequencies of detection for the 16 substances were compared between the EDA and control areas.[1] The method of analysis was the Mantel-Haenszel procedure. This procedure assumes similar patterns across those media that contain one positive sample; if a chemical is found in one medium in a region, it is assumed that the chemical may be found in the other media in the same region. The finding of no detectable levels in both regions has no effect on the assumptions.

The results of Mantel-Haenszel analysis are shown in table D-5. The EDA was found to have a significantly higher frequency of positive detections than the control area for four chemicals: 1,2- and 1,3-dichlorobenzene, 2- and 4-chlorotoluene. Table D-1 illustrates the results for one compound, 1,2-dichlorobenzene. A higher rate of positive samples was found in the EDA and the difference is statistically significant.* The odds of finding a positive sample in the EDA is 7.5 times greater than that for the control areas. It should be noted that no comparison can be made with six of the submedia, as no control samples were analyzed. The EPA data used in this analysis are presented in tables D-2, D-3, and D-4. EPA found significant differences for 2-chlorotoluene and 1,2-dichlorobenzene in air between EDA and control areas. It should be noted that 1,4-dichlorobenzene was found to be more frequently detected in the control areas than in the EDA. The absence of significant differences for the other compounds may be due to inadequate sampling for controls and cannot be interpreted as strong evidence that the EDA and controls are similar in levels of contamination. It should be noted that these same four chemicals were detected in leachate sludge obtained at the

Table D-1.—Odds Ratio[a] and Detection Rates for 1,2-Dicholorobenzene

	EDA v. control area	Love Canal v. control area
	7.5 (.001)	4.2 (.05)
Medium	EDA	Control area
Shallow well	0.0[b]	0.0
	47[c]	11
Deep well	0.04	0.0
	28	14
Sump water	0.0	0.0
	104	4
Surface water	0.0	0.0
	4	5
Drinking water	0.0	0.0
	30	4
Storm sewer water	0.11	0.0
	9	1
Sanitary sewer water	1.00	—
	1	0
Soil	0.01	0.0
	105	9
Storm sewer sediment	0.07	—
	15	0
Surface water sediment	0.30	0.0
	4	4
Living area air	0.42	0.10
	539	30
Basement air	0.34	—
	86	0
Outdoor air	0.10	—
	83	0
Oatmeal	—	—
	0	0
Potatoes	—	—
	0	0
Crayfish	0.0	0.0
	31	9
Mice	0.0	0.0
	35	32
Worms	0.0	0.0
	19	5

[a]The odds ratio (P-value) indicates the odds of observing a sample with 1,2-dicholorobenzene in one region compared to another.
[b]Frequency of samples containing 1,2-dichlorobenzene.
[c]Total number of samples analyzed.

SOURCE: Cupples, op. cit.

[1]L. A. Cupples, Boston University School of Public Health, report submitted to OTA, Industry, Technology, and Employment Program, May 1983.
*Significant refers to a 90-percent confidence level or greater.

Table D-2.—Detection (+) of Indicator Substance and Numbers of Samples Analyzed (n) for Environmental Media in the Control Areas

Indicator substance	Environmental media and submedia[a]																					
	1 +/n	2 +/n	3 +/n	4 +/n	5 +/n	6 +/n	7 +/n	8 +/n	9 +/n	10 +/n	11 +/n	12 +/n	13 +/n	14 +/n	15 +/n	16 +/n	17 +/n	18 +/n	19 +/n	20 +/n	21 +/n	22 +/n
Gamma-BHC (Lindane)	3/11	3/15	1/5	0/5	0/5	0/1	0/0	0/9	0/0	0/0	0/0	3/5	0/28	0/0	0/0	0/0	0/0	0/9	0/0	0/0	1/33	0/5
Chlorobenzene	0/11	3/16	0/5	0/5	1/5	0/1	0/0	0/17	0/0	0/1	0/0	0/4	0/31	0/0	0/0	0/4	0/3	0/0	0/0	0/0	0/0	0/0
1,2-Dichlorobenzene	0/11	0/14	0/4	0/5	0/4	0/1	0/0	0/9	0/0	0/0	0/0	0/4	3/30	0/0	0/0	0/0	0/0	0/9	0/0	0/0	0/32	0/5
1,3-Dichlorobenzene	0/11	0/14	0/4	0/5	0/4	0/1	0/0	0/9	0/0	0/0	0/0	0/4	0/0	0/0	0/0	0/0	0/0	0/9	0/0	0/0	0/32	0/5
1,4-Dichlorobenzene	0/11	0/14	0/4	0/5	0/4	0/1	0/0	0/9	0/0	0/0	0/0	2/4	18/30	0/0	0/0	0/0	0/0	0/9	0/0	0/0	0/32	1/5
1,2,3-Trichlorobenzene	0/11	0/14	0/4	0/5	0/4	0/1	0/0	0/9	0/0	0/0	0/0	0/4	0/28	0/0	0/0	0/0	0/0	0/9	0/0	0/0	0/32	0/5
1,2,4-Trichlorobenzene	0/11	0/14	0/4	0/5	0/4	0/1	0/0	0/9	0/0	0/0	0/0	1/4	0/28	0/0	0/0	0/0	0/0	0/9	0/0	0/0	1/32	1/5
1,3,5-Trichlorobenzene	0/11	0/14	0/4	0/5	0/4	0/1	0/0	0/9	0/0	0/0	0/0	0/4	0/28	0/0	0/0	0/0	0/0	0/9	0/0	0/0	0/32	0/5
1,2,3,4-Tetrachlorobenzene	0/11	0/14	0/4	0/5	0/4	0/1	0/0	0/9	0/0	0/0	0/0	0/4	0/28	0/0	0/0	0/0	0/0	0/9	0/0	0/0	10/32	0/5
1,2,3,5-Tetrachlorobenzene	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0
1,2,4,5-Tetrachlorobenzene	0/11	0/14	0/4	0/5	0/4	0/1	0/0	0/9	0/0	0/0	0/0	0/4	0/0	0/0	0/0	0/0	0/0	0/9	0/0	0/0	0/32	0/5
Pentachlorobenzene	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/28	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0
Hexachlorobenzene	0/11	0/14	0/4	0/5	0/4	0/0	0/0	0/9	0/0	0/0	0/0	0/4	0/28	0/0	0/0	0/0	0/0	0/9	0/0	0/0	0/32	0/5
2-Chloronaphthalein	0/11	0/14	0/4	0/5	0/4	0/1	0/0	0/9	0/0	0/0	0/0	0/4	0/0	0/0	0/0	0/0	0/0	0/9	0/0	0/0	0/0	0/5
α-Chlorotoluene	0/11	0/16	0/5	0/3	0/5	0/1	0/0	0/17	0/0	0/1	0/0	0/4	0/0	0/0	0/0	0/4	0/3	0/0	0/0	0/0	0/0	0/0
2-Chlorotoluene	0/11	0/16	0/5	0/3	0/5	0/1	0/0	0/17	0/0	0/1	0/0	0/4	2/30	0/0	0/0	0/4	0/3	0/0	0/0	0/0	0/0	0/0
3-Chlorotoluene	1/11	2/16	0/5	0/3	0/5	0/1	0/0	0/17	0/0	0/1	0/0	0/4	0/0	0/0	0/0	0/4	0/3	0/0	0/0	0/0	0/0	0/0
4-Chlorotoluene	0/11	0/16	0/5	0/3	0/5	0/1	0/0	0/17	0/0	0/1	0/0	0/4	2/31	0/0	0/0	0/4	0/3	0/0	0/0	0/0	0/0	0/0
2,4-Dichlorotoluene	0/11	0/14	0/4	0/5	0/4	0/1	0/0	0/9	0/0	0/0	0/0	1/4	0/0	0/0	0/0	0/0	0/0	0/9	0/0	0/0	6/32	0/5
α,α,2,6-Tetrachlorotoluene	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0
Totals	4/187	8/249	1/74	0/77	1/74	0/17	0/0	0/193	0/0	0/5	0/0	7/69	25/348	0/0	0/0	0/20	0/15	0/108	0/0	0/0	18/353	2/60
Detection frequencies (%)	2.1	3.2	1.4	0	1.4	0	—	0	—	0	—	10.1	7.2	—	—	0	0	0	—	—	5.1	3.3

[a]**Water:**
1) shallow well,
2) deep well,
3) sump,
4) surface,
5) drinking,
6) storm sewer,
7) sanitary sewer;

Soil:
8) soil,

Sediment:
9) sump,
10) storm sewer,
11) sanitary sewer,
12) surface water;

Air:
13) living area,
14) basement,
15) outdoor; and

Biota:
16) oatmeal,
17) potatoes,
18) crayfish,
19) dog,
20) maple,
21) mice,
22) worms.

SOURCE: US/EPA, op. cit., vol. III.

Table D-3.—Detection (+) of Indicator Substance and Numbers of Samples Analyzed (n) for Environmental Media in the EDA

Indicator substance	Environmental media and submedia[a] 1 +/n	2 +/n	3 +/n	4 +/n	5 +/n	6 +/n	7 +/n	8 +/n	9 +/n	10 +/n	11 +/n	12 +/n	13 +/n	14 +/n	15 +/n	16 +/n	17 +/n	18 +/n	19 +/n	20 +/n	21 +/n	22 +/n
Gamma-BHC (Lindane)	12/47	3/29	19/105	1/3	3/31	4/7	1/1	7/109	0/0	6/13	0/0	4/4	2/292	0/84	0/79	0/0	0/0	0/31	0/0	0/0	0/36	0/8
Chlorobenzene	1/43	2/30	2/104	0/4	7/31	0/9	0/1	3/212	0/0	3/15	0/1	3/4	8/540	1/86	2/83	0/13	0/12	0/0	0/0	0/0	0/0	0/0
1,2-Dichlorobenzene	0/47	1/28	0/104	0/4	0/30	1/9	1/1	1/105	0/0	1/15	0/0	2/4	227/539	29/86	8/83	0/0	0/0	0/31	0/0	0/0	0/35	0/19
1,3-Dichlorobenzene	0/47	1/28	2/104	0/4	0/30	1/9	1/1	0/105	0/0	1/15	0/0	2/4	0/0	0/0	0/0	0/0	0/0	0/31	0/0	0/0	1/35	0/19
1,4-Dichlorobenzene	0/47	1/28	12/104	0/4	0/30	1/9	0/1	1/105	0/0	1/15	0/0	2/4	81/539	14/86	1/83	0/0	0/0	0/31	0/0	0/0	0/35	0/19
1,2,3-Trichlorobenzene	0/47	0/28	0/104	0/4	0/15	2/9	1/1	0/105	0/0	0/7	0/0	1/4	0/292	0/84	1/79	0/0	0/0	0/31	0/0	0/0	0/35	0/19
1,2,4-Trichlorobenzene	0/47	0/28	0/104	0/4	0/30	3/9	1/1	0/105	0/0	6/15	0/0	2/4	6/292	0/84	1/79	0/0	0/0	0/31	0/0	0/0	0/35	4/19
1,3,5-Trichlorobenzene	0/47	0/28	0/104	0/4	0/15	0/9	1/1	0/105	0/0	0/6	0/0	0/4	0/292	0/84	1/79	0/0	0/0	0/31	0/0	0/0	0/35	0/19
1,2,3,4-Tetrachlorobenzene	0/47	0/28	0/104	0/4	0/15	2/9	1/1	0/105	0/0	3/6	0/0	2/4	15/292	3/84	0/79	0/0	0/0	0/31	0/0	0/0	0/35	0/19
1,2,3,5-Tetrachlorobenzene	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0
1,2,4,5-Tetrachlorobenzene	0/47	0/28	0/104	0/4	0/15	2/9	1/1	0/105	0/0	1/6	0/0	0/3	0/0	0/0	0/0	0/0	0/0	0/31	0/0	0/0	0/34	0/19
Pentachlorobenzene	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	2/291	0/84	0/77	0/0	0/0	0/0	0/0	0/0	0/0	0/0
Hexachlorobenzene	0/47	0/28	1/104	0/4	0/30	0/9	1/1	0/104	0/0	1/15	0/0	2/4	0/292	0/84	0/78	0/0	0/0	1/31	0/0	0/0	0/35	0/19
2-Chloronaphthalein	0/47	0/28	0/104	0/4	0/30	0/9	1/1	0/105	0/0	0/15	0/0	1/4	0/0	0/0	0/0	0/0	0/0	0/31	0/0	0/0	0/35	0/19
α-Chlorotoluene	0/43	0/31	0/90	0/0	0/31	0/9	0/1	0/213	0/0	0/6	1/1	0/4	0/0	0/0	0/0	0/13	0/12	0/0	0/0	0/0	0/0	0/0
2-Chlorotoluene	0/43	1/30	0/90	0/0	0/31	1/8	0/0	0/213	0/0	0/6	0/0	2/4	141/541	14/86	12/83	0/13	0/12	0/0	0/0	0/0	0/0	0/0
3-Chlorotoluene	0/43	4/30	0/90	0/0	0/31	1/8	0/0	0/213	0/0	0/6	0/0	2/4	0/0	0/0	0/0	0/13	0/12	0/0	0/0	0/0	0/0	0/0
4-Chlorotoluene	0/43	1/30	0/90	0/0	0/31	1/8	0/0	0/213	0/0	0/6	0/0	2/4	69/541	12/86	7/83	0/13	0/12	0/0	0/0	0/0	0/0	0/0
2,4-Dichlorotoluene	0/47	1/28	0/104	0/4	0/15	1/9	1/1	0/104	0/0	0/9	0/0	1/4	0/0	0/0	0/0	0/0	0/0	5/31	0/0	0/0	0/35	3/19
α,α,2,6-Tetrachlorotoluene	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0
Totals	13/779	15/448	36/1,673	1/51	10/441	20/148	11/14	12/2,326	0/0	23/167	1/2	28/67	451/4,737	73/1,018	33/965	0/65	0/60	6/372	0/0	0/0	9/419	7/217
Detection frequencies (%)	1.7	3.1	2.2	2.0	2.3	13.5	78.6	0.5	0	13.8	50.0	41.8	0.1	7.2	3.4	0	0	1.6	0	0	2.1	3.2

[a]**Water:**
1) shallow well,
2) deep well,
3) sump,
4) surface,
5) drinking,
6) storm sewer,
7) sanitary sewer;

Soil:
8) soil,

Sediment:
9) sump,
10) storm sewer,
11) sanitary sewer,
12) surface water;

Air:
13) living area,
14) basement,
15) outdoor; and

Biota:
16) oatmeal,
17) potatoes,
18) crayfish,
19) dog,
20) maple,
21) mice,
22) worms.

SOURCE: US/EPA, op. cit., vol. III.

Table D-4.—Detection (+) of Substances Not Found in Control Areas and Numbers of Samples Analyzed (n) for Environmental Media in the EDA

Indicator substance	Environmental media and submedia[a]																					
	1 +/n	2 +/n	3 +/n	4 +/n	5 +/n	6 +/n	7 +/n	8 +/n	9 +/n	10 +/n	11 +/n	12 +/n	13 +/n	14 +/n	15 +/n	16 +/n	17 +/n	18 +/n	19 +/n	20 +/n	21 +/n	22 +/n
2-Chlorophenol	0/47	1/27	0/104	0/4	0/30	0/9	0/1	0/104	0/0	0/15	0/1	1/4	0/0	0/0	0/0	0/0	0/0	0/31	0/0	0/0	0/35	0/19
4-Chlorophenol	1/35	3/24	2/92	0/4	0/15	0/5	0/1	0/71	0/0	0/15	0/1	0/4	0/0	0/0	0/0	0/0	0/0	0/31	0/0	0/0	0/35	0/19
2-Nitrophenol	0/47	0/28	0/104	0/4	0/30	0/9	0/1	0/104	0/0	0/15	0/1	0/4	0/0	0/0	0/0	0/0	0/0	0/31	0/0	0/0	0/35	0/19
2,3,6-Trichlorophenol	0/36	0/24	0/92	0/4	0/15	0/5	0/1	0/71	0/0	0/5	0/1	0/4	0/0	0/0	0/0	0/0	0/0	0/31	0/0	0/0	0/35	0/19
4-Chloro-3-methylphenol	0/47	0/28	0/104	0/4	0/30	0/9	0/1	0/104	0/0	0/15	0/1	0/4	0/0	0/0	0/0	0/0	0/0	0/31	0/0	0/0	1/35	1/19
1,3,5-Trichlorobenzene	0/47	0/28	0/104	0/4	0/15	0/9	1/1	0/105	0/0	0/6	1/1	0/4	0/292	0/84	1/79	0/0	0/0	0/31	0/0	0/0	0/35	0/19
Acenaphthylene	2/47	2/28	1/104	0/4	0/30	0/9	0/1	2/105	0/0	0/15	0/1	0/4	0/0	0/0	0/0	0/0	0/0	0/31	0/0	0/0	0/35	0/19
Dibenzo (a,h) anthracene	0/47	0/28	0/104	0/4	0/15	0/9	0/1	0/105	0/0	0/15	0/1	0/4	0/0	0/0	0/0	0/0	0/0	0/31	0/0	0/0	0/35	0/19
2,4,6-Trichloroaniline	0/47	0/28	0/104	0/4	0/15	0/9	0/1	0/105	0/0	0/6	0/1	0/4	0/0	0/0	0/0	0/0	0/0	0/31	0/0	0/0	0/34	0/19
1,2,4,5-Tetrachlorobenzene	0/47	0/28	0/104	0/4	0/15	2/9	1/1	0/105	0/0	1/6	1/1	0/3	0/0	0/0	0/0	0/0	0/0	0/31	0/0	0/0	0/34	0/19
Acrylonitrile	0/43	0/31	0/104	0/4	0/31	0/9	0/1	0/213	0/0	0/6	0/1	0/4	0/0	0/0	0/0	0/13	0/12	0/0	0/0	0/0	0/0	0/0
1,1,2-Trichloroethane	0/43	1/31	0/103	0/4	2/31	0/9	0/1	0/213	0/0	0/15	0/1	0/4	0/0	0/0	0/0	0/13	0/12	0/0	0/0	0/0	0/0	0/0
1,2-Dichloroethane	1/43	0/31	1/104	0/4	0/31	0/9	0/1	0/213	0/0	0/15	0/1	0/4	0/0	0/0	0/0	7/13	0/12	0/0	0/0	0/0	0/0	0/0
Totals	4/576	7/364	4/1,327	0/52	2/303	2/109	2/13	2/1,618	0/0	1/149	2/13	1/51	0/292	0/84	1/79	7/39	0/36	0/310	0/0	0/0	1/348	1/190
Detection frequencies (%) (Control = 0%)	0.7	1.9	0.3	0	0.7	1.8	15.4	0.1	0	0.7	15.4	2.0	0	0	1.3	18.0	0	0	—	—	0.3	0.5

[a]**Water:**
1) shallow well,
2) deep well,
3) sump,
4) surface,
5) drinking,
6) storm sewer,
7) sanitary sewer;

Soil:
8) soil,

Sediment:
9) sump,
10) storm sewer,
11) sanitary sewer,
12) surface water;

Air:
13) living area,
14) basement,
15) outdoor; and

Biota:
16) oatmeal,
17) potatoes,
18) crayfish,
19) dog,
20) maple,
21) mice,
22) worms.

SOURCE: US/EPA, op. cit., vol. III.

Love Canal treatment facility in volumes approaching 1 percent of the total sludge volume.[2]

A finding that 4 out of 16 chemicals known to have been disposed in the canal landfill calls into question the EPA conclusion that EDA is not contaminated by Love Canal chemicals except for sediments of storm sewers and surface water sediments at sewer discharge points. The discrepancy between the OTA and EPA finding can be explained. EPA aggregated data for 150 compounds including 129 priority pollutants, the majority of which were not known to have been disposed in the canal landfill. OTA focused on only those chemicals with a history of disposal.

The detection of four substances at higher frequencies in the EDA does not necessarily mean that these substances originated in the canal landfill. Frequencies of detection for 12 indicator substances were not significantly different and one had a greater frequency of detection in the control areas. It is to be expected that, at the 90-percent confidence level applied in these statistical analyses, 10 percent of the statistical tests showing significance might be in error. In this case, this means that 1.6 (or really 2) of the 16 analyses might be a result of chance. However, two or possibly four of the significant differences could be real indications of contamination in the EDA as compared to the control areas.

[2]U.S. Environmental Protection Agency, *Analysis of the Love Canal Treatment Plant Sludge Sample*, memo from W. L. Budde, J. W. Eichelberger, P. Olynk to T. Hauser, Aug. 22, 1980.

Table D-5.—Summary of Mantel-Haenszel Results

Indicator substance	EDA v. control area	Love Canal v. control area
Lindane	No	No
Chlorobenzene	No	Yes
1,2-Dichlorobenzene	Yes	Yes
1,3-Dichlorobenzene	Yes	Yes
1,4-Dichlorobenzene	(a)	(a)
1,2,3-Trichlorobenzene	No	No
1,2,4-Trichlorobenzene	No	Yes
1,3,5-Trichlorobenzene	—	No
1,2,3,4-Tetrachlorobenzene	No	No
1,2,3,5-Tetrachlorobenzene	—	—
1,2,4,5-Tetrachlorobenzene	No	No
Pentachlorobenzene	No	—
Hexachlorobenzene	No	Yes
2-Chloronaphthalene	No	—
0-Chlorotoluene	—	—
2-Chlorotoluene	Yes	Yes
3-Chlorotoluene	No	No
4-Chlorotoluene	Yes	Yes
2,4-Dichlorotoluene	No	No
α,α,2,6-Tetrachlorotoluene	—	—

Yes: Significantly greater contamination in EDA (Love Canal).
No: No significant difference between areas.
—: Insufficient data.
(a): Control area shows significantly greater contamination.

SOURCE: Cupples, op. cit.

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